REPORT

Feasibility Study

General Electric Company
Transmission Systems
Fort Edward, New York

January 1997

O'BRIEN & GERE
ENGINEERS, INC.

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REPORT

FEASIBILITY STUDY

GENERAL ELECTRIC COMPANY
TRANSMISSION SYSTEMS
FORT EDWARD, NEW YORK

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January 1997

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1. Introduction

1.1. General background

This feasibility study (FS) has been developed by O'Brien & Gere Engineers, Inc. (O'Brien & Gere) on behalf of the General Electric Company (GE). This FS was conducted pursuant to Order on Consent Index #A5-0316-94-06 (Order) between the State of New York Department of Environmental Conservation (NYSDEC) and GE. The FS was conducted in accordance with the Feasibility Study Work Plan (Work Plan; O'Brien & Gere, 1995), which was approved by NYSDEC on December 15, 1995.

The FS has been conducted in accordance with provisions of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as amended, the National Contingency Plan (NCP 1990), USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (1988)*, and the State of New York's Inactive Hazardous Waste Disposal Site law and implementing regulations. Completion of this work is also intended to satisfy corrective action obligations related to the facility pursuant to the Solid Waste Disposal Act as amended by the Resource Conservation and Recovery Act (RCRA) and the Hazardous and Solid Waste Amendments (HSWA) and the New York Environmental Conservation Law ECL Article 27, Title 9.

1.2. Project objectives

During the past two decades, GE, in consultation with NYSDEC and the New York State Department of Health (NYSDOH), has sought to address remedial issues at the Fort Edward facility. The measures implemented to address these issues have been significant and effective at curtailing the migration of contaminants.

A comprehensive RI/FS has been implemented at the site to expand and integrate investigation and remedial activities at and in the vicinity of the Fort Edward facility.

The specific objective for this FS is to develop and evaluate remedial alternatives which address contamination on a site-wide basis, such that a cost-effective remedy can be proposed for the site which is protective of human health and the environment and meets pertinent regulatory requirements.

1.3. Report organization

This report is organized as follows:

Section 1 - Introduction. Information regarding project overview and objectives and document organization is presented in Section 1 of this report.

Section 2 - Site conditions. Section 2 contains a summary of existing site conditions as defined by investigatory and interim remedial measure (IRM) activities conducted at the site.

Section 3 - Development of alternatives. This section describes the remedial action objectives; general response actions; quantity of materials to be addressed by remedial alternatives; identification; screening; and evaluation of remedial technologies and process options; and the remedial alternatives.

Section 4 - Identification of ARARs. Section 4 describes applicable or relevant and appropriate requirements (ARARs) considered during the detailed analysis of alternatives.

Section 5 - Detailed analysis of alternatives. The ability of each alternative to satisfy relevant criteria is evaluated on an individual and comparative basis in Section 5.

Section 6 - Conclusions and recommendations. The basis for selection and recommendation of an alternative is presented in Section 6.

1.4. Previous remedial activities

Since 1976, numerous improvements and remedial actions have been undertaken by GE at the Fort Edward facility to reduce the potential impact of the site on the surrounding area. These actions include, but are not limited to, the following:

- Polychlorinated biphenyls (PCBs) abatement program conducted pursuant to the 1976 Agreement with the State of New York;
- In accordance with NYSDOH recommendations, GE paid for and caused installation of water mains and piping for households on Park Avenue, Stevens Lane, Ethan Allen Street and Putnam Avenue;
- NYSDEC-approved on-site and off-site remedial plans were implemented pursuant to Order on Consent #T032785;
- In 1988, shallow bedrock ground water recovery and treatment was initiated in wells GM-8DR and GM-11D. A plan to upgrade the bedrock ground water recovery system was approved by NYSDEC and implemented in 1990;
- Since 1992, several upgrades to the Fort Edward plant wastewater treatment facility have been implemented to reduce effluent loading to the Hudson River; and
- With the approval of NYSDEC and NYSDOH, GE undertook a voluntary residential well sampling and public water supply connection program in the areas south, east and west of the Fort Edward facility in 1994. To date, 31 homes and businesses in the Town of Fort Edward have agreed to be connected to public water at no charge to the owners.

1.4.1. PCB abatement project

In 1976, pursuant to the 1976 Agreement with the State of New York, GE implemented a PCB abatement program. The abatement program consisted of sealing floor drains and trenches, replacing sections of sewer pipelines, construction of an industrial water treatment plant and collection basin, and installation of concrete curbing around the tank farm.

Portions of the old sewer system were replaced with mechanically sealed cast iron or ductile iron pipe (DIP) lines. Additional modifications to the wastewater management system included replacement and rerouting of wastewater to a newly constructed wastewater collection and treatment system.

The new treatment system consisted of a 40,000 gpd extended aeration system to treat sanitary wastes, a concrete equalization basin, and a state of the art industrial wastewater treatment facility (WTF).

1.4.2. Off-site ground water recovery

Following completion of the off-site FS of remedial alternatives (Lawler, Matusky, & Skelly Engineers; LMS 1988) and subsequent NYSDEC approval, a ground water recovery well was installed in October 1989. Recovery well RW-2 was installed approximately 450 feet south of the plant near state monitoring well SW-3. This recovery well was installed to collect ground water from the area south of the plant. Recovered ground water continues to be pumped from RW-2 back to the plant site and treated at the Fort Edward facility WTF.

1.4.3. On-site remediation

Pursuant to the NYSDEC-approved remedial program, an on-site remedial plan was prepared by Dunn Geoscience Corporation (Dunn 1990a). The on-site plan involved several components, as described below.

Recovery well system. Following completion of the on-site RI/FS (LMS 1989), a multiple recovery well system was designed for the shallow, unconsolidated deposits to increase the effectiveness and efficiency of the ground water recovery treatment system. In accordance with the NYSDEC-approved Fort Edward plant on-site remedial plan (Dunn 1990a), the new system was installed in June and July 1991 and consisted of five on-site recovery wells (RW-1A, RW-3, RW-4, RW-5 and RW-6) located north of Park Avenue on the southeastern boundary of the facility. The initial annual report following the redesign and installation of the ground water recovery system was prepared by Dunn in April 1993. The most recent report on the operation of the ground water collection and treatment system was prepared by O'Brien & Gere and submitted to NYSDEC in June 1996 (O'Brien & Gere 1996a). By the end of 1996, over 300 million gallons of ground water had been pumped from the shallow unconsolidated unit and treated.

Air stripping system. As part of the on-site remedial plan, a new fiberglass reinforced plastic (FRP) air stripper tower was installed to treat ground water recovered from the on-site collection system. The air stripper is 32 feet tall, four feet in diameter and is designed to be self supporting. The air stripper contains a polypropylene mist eliminator and is filled with polypropylene packing media supported on FRP grating. The air stripper is equipped with a single radial type air blower. The blower motor is a squirrel cage type, two speed 15 horse power, 480 volt, three phase type constructed of cast iron and steel. Controls for the air stripper are located inside the Westvaco building. The system is equipped with a high level switch designed to shut off the blower and well pumps in the event of high water conditions in the stripper tower.

Effluent from the air stripper is conveyed to a manhole proximate to the air stripper through a six inch diameter, cast iron pipe. Flow from the manhole is piped directly to the equalization basin where it is collected and treated in the WTF.

PCB contaminated material removal. Based on the results of the soil sampling program conducted in 1987 and the NYSDEC-approved remedial program for the Fort Edward facility, a soils removal action consisting of the excavation of soil containing PCBs in excess of 25 mg/kg was implemented (Dunn 1990a). The PCB contaminated material removal action was performed by Jet-Line Services, Inc. under the supervision of Dunn. A final report on the Fort Edward plant site PCB contaminated material removal action was prepared by Dunn. As described in the report, excavation, transportation and disposal of PCB contaminated materials from the PCB unloading area and leachfield was implemented in 1990. Approximately 718 tons of material was excavated and transported off-site for disposal at an approved facility. Post excavation samples were collected for PCB analysis to verify that the remaining soils did not exceed 25 mg/kg.

Shallow bedrock ground water recovery. Based on the historic detections of PCBs and VOCs in shallow bedrock monitoring wells GM-8D(R) and GM-11D, the wells were converted to shallow bedrock ground water recovery wells in 1988.

A plan to upgrade the shallow bedrock ground water recovery wells was submitted to NYSDEC in a March 23, 1990 report for wells GM-11D and GM-8DR. The report was reviewed and approved by NYSDEC on August 15, 1990. Briefly, the approved shallow bedrock remedial program consisted of the installation of a submersible pump and piping at wells GM-8DR and GM-11D, recompletion of well GM-8DR with a 4-inch ID stainless steel well screen, and treatment of collected ground water at the permitted on-site treatment system.

1.4.4. Dense non-aqueous phase liquid (DNAPL) recovery

Monitoring well GM-27 was installed in November 1983 to measure water-level changes during pumping of recovery well RW-1. Subsequently, PCB oil was detected in the bottom of the well (Geraghty & Miller 1983). A peristaltic pump was installed to recover DNAPL in well GM-27 and was operated intermittently for six years. A total of approximately 1,327 gallons of oil have been collected from GM-27. To more precisely define ground water quality in the southern portion of the plant, a shallow ground water monitoring well, designated DGC-41, was installed in April 1990 between recovery well RW-1 and monitoring well GM-16. Well development activities at DGC-41 revealed the presence of PCB oil in DGC-41 as well (Dunn 1990b).

During late May and early June 1990, a supplemental hydrogeologic investigation, which included installation of 24 test borings, was conducted to assess the extent of subsurface DNAPL in the southern portion of the plant (Dunn 1990b). Results of the test boring program indicated that subsurface PCB oils were present in relatively small areas in and around monitoring wells GM-27 and DGC-41. Two DNAPL recovery wells (ORW-1 and ORW-2) were subsequently installed adjacent to these wells and have been operating intermittently since December 1991.

Since initiation of recovery activities at ORW-1 in February 1991, approximately 57 gallons of DNAPL have been recovered and sent off-site for proper disposal. The estimated volume of recoverable DNAPL in the vicinity of recovery well ORW-1 (based on 1990 observations) is 1,050 gallons. Despite the replacement of the product recovery pump in 1993 and subsequent modifications to improve the performance of ORW-1, rates of DNAPL recovery continue to be low.

Since initiation of oil recovery activities at ORW-2 in October 1992, approximately 625 gallons of DNAPL have been recovered and sent to the GE Fort Edward hazardous waste container storage area for off-site disposal. Additional details on the operation and performance of the two DNAPL recovery wells is contained in a report submitted to NYSDEC in 1994 (O'Brien & Gere 1994a) and in the most recent Annual Ground Water Monitoring and Remedial Systems Operation Reports (O'Brien & Gere 1996a).

1.4.5. Other remedial measures

Remedial measures that have been conducted previously at the Fort Edward plant site are described below.

Installation of RW-1. As a means of mitigating the VOC plume identified in 1983 by Geraghty & Miller, a shallow ground water recovery well, RW-1, was installed in August 1983 as part of a NYSDEC-approved interim remedial measure. The well was located along Park Avenue in the southeast portion of the facility and the ground water was pumped to an on-site water treatment facility (air stripper). In December 1988, recovery well RW-1A was installed as a replacement for recovery well RW-1. The well was replaced due to ongoing problems of reduced well yields in RW-1, most likely caused by iron bacteria and other biofouling problems.

Sealing of production wells. As reported in the 1985 RI Report (LMS, 1985), two on-site wells formerly utilized as ground water production wells at the plant, were sampled and analyzed for PCBs and VOCs. Historically, concentrations of PCBs up to 33,000 μg/L and 4,000 μg/L of total VOCs were detected in PW-1. Additionally, a total PCB concentration of 9.3 μg/L was reported in PW-2 (LMS, 1985). Based on the available data, it was concluded that PCBs and VOCs detected in the wells were the results of leakage in the immediate vicinity of the wells. The two on-site production wells were sealed with a wood/rubber packer and bentonite in an attempt to prevent contaminants from entering the deep aquifer.

Former production wells PW-1 and PW-2 were permanently decommissioned during the period from June 27 to July 6, 1995 by sealing the entire length of each borehole with a combination of cement-bentonite grout and bentonite chips. Well decommissioning activities were performed by Parratt-Wolff, Inc. of East Syracuse, New York. Well decommissioning activities were observed by O'Brien & Gere personnel.

Decommissioning activities were performed by tremi-grouting from the bottom of the borehole, forcing other fluids upward. The grout was placed into the borehole through the inside of the 2¼-inch ID support pipe. At the conclusion of the borehole grouting program each of the temporary well seals were grouted in place within the upper portion of each of the boreholes.

The ground water displaced from each of the boreholes during grouting activities was containerized in a temporary storage tank. This ground water was characterized and, after receiving approval by NYSDEC's Division of Water, was discharged to the on-site equalization basin for subsequent treatment at the WTF.

Outfall 004 diversion. Installation of a temporary outfall diversion was completed in April 1994. The outfall diversion consisted of installation of a new piping system constructed of flexible PVC. The new system was raised above the shoreline such that water discharged directly into the

Hudson River without coming in contact with sediments or the river bank. On May 24, 1994, GE submitted a plan to NYSDEC to complete the temporary closure of river-end portions of the 30-inch former Outfall 004 line.

On July 18, 1994, GE removed the 30-inch ID corrugated metal pipe (CMP) outfall from the steep bank back to the elbow near the concrete headwall. The remaining 40-ft section of 30-inch ID CMP from the headwall back to manhole (MH) 1 was filled with concrete and the exposed end was capped. Following removal of the CMP pipe, it was estimated that up to 5 gpm of water was flowing from the bank around the former 004 outfall pipe. Completion of the activities described below, including the former outfall 004 pipeline IRM, addressed the potential for this flow to transport PCBs to the Hudson River, as described below.

In October 1994, the remaining pipe between the top of the bank and manhole MH-1 was removed, including the thrust block and concrete saddle below the thrust block, several 4-ft sections of 36-inch reinforced concrete pipe (RCCP), and a section of 6-inch vitrified clay pipe (VCP) drainage tile. Samples of pipe bedding beneath the 36-inch RCCP exhibited PCB concentrations of 1,400 and 3,800 mg/kg. Results of a soil sample representing fill material adjacent to the RCCP on top of the bedding was non-detect for PCB. The excavation was backfilled with a 60/40 percent mixture of carbon and sand wrapped in filter fabric as a construction measure. The results of these investigations and IRMs are contained in a report entitled "Outfall 004 Investigation Report" (Dames & Moore 1994b).

In January and February 1996, work on the permanent outfall diversion was completed. The 6-inch diameter outfall was relocated approximately 200 feet upstream and involved installing new underground piping from the tie-in to the existing outfall pipeline to a new concrete headwall erected near the edge of the river (just above the high water level).

From the headwall out to the river, the pipe is constructed of high density polyethylene (HDPE). Between the river and the top of the bank, the new 6-inch outfall pipe is constructed of ductile iron and is installed within a 12-inch diameter casing grouted into an angled borehole drilled parallel to the steep slope. A new manhole was installed at the top of the bank at the point where the pipeline departs from the horizontal and starts to angle down the steep bank.

Former Outfall 004 Pipeline IRM (1996). In accordance with a NYSDEC-approved IRM work plan and the 1995 Consent Order, over 600 feet of the former Outfall 004 pipeline and pipe bedding was removed from the area west of Manhole #4 to the top of the steep bank above the Hudson River.

Between January and May 1996, more than 4,100 tons of PCB contaminated material was removed and transported to the TSCA-permitted landfill operated by Chemical Waste Management in Model City, New York. Details of the IRM are contained in the summary report and engineering certification submitted to the NYSDEC in July 1996 (O'Brien & Gere 1996b).

1.4.6. RCRA corrective action

As specified in the draft Part 373 Permit and the RI/FS work plan (O'Brien & Gere, 1995), the following solid waste management units (SWMUs) have been identified as not requiring further investigation or corrective action:

- SWMU #2 - Bay Storage Area (CS-2)
- SWMU #3 - Bldg. 31 Hazardous Waste Storage (CS-3)
- SWMU #4 - Oil House Storage Area (CS-4)
- SWMU #7 - TCE Still (WRU-1)
- SWMU #8 - 1,1,1-ATCA Still (WRU-2)
- SWMU #9 - Waste TCE Storage Tank (ST-1)
- SWMU #17 - Waste Kerosene Tank (ST-6)
- SWMU #18 - Waste Kerosene Tank
- SWMU #19 - New Waste Kerosene Storage Area (ST-8)

In 1990, soil from beneath the following SWMUs were excavated and disposed off-site:

- SWMU #5 - Closed Pyranol Unload Area (TS-1)
- SWMU #10 - Former PCB Railroad Storage Tank (ST-2)
- SWMU #12 - Former PCB Railroad Storage Tank (ST-4)

The corrective action requirements for the following SWMUs were addressed through closure of the units, as described in the Closure Plan submitted on April 1, 1991 and approved by NYSDEC on January 7, 1992:

- SWMU #11 - PCB Railroad Storage Tank (ST-3)
- SWMU #13 - PCB Railroad Storage Tank (ST-5)

The following SWMUs and other areas are being addressed by the remediation conducted pursuant to Order on Consent Index T032785. Remedial operation and maintenance activities related to these SWMUs and other areas is continuing:

- SWMU #1 - Past Drum Storage Area
- SWMU #5 - Pyranol Unload Area (TS-1)
- SWMU #10 - PCB Railroad Storage Tank (ST-2)
- SWMU #12 - PCB Railroad Storage Tank (ST-4)
- SWMU #14 - Sanitary Leachfield (LF-1)
- Ground Water Contamination
- PCB Contaminated DNAPL Pools

Mineral oil tank removal. In September 1991, a 10,000 gallon underground storage tank was removed under the supervision of Mr. Thomas Swerden, NYSDEC Regional Spill Inspector. This tank was removed from the area immediately west of the Foil Mill and south of the electrical substation. The tank was used to store raw mineral oil. During the removal of this 10,000 gallon storage tank, visual contamination was identified in the upper silty/sand layer which was in the vicinity of the tank. Also the tank was identified as having a hole approximately one inch in diameter, located about 2/3 of the way up from the bottom of the tank. Soils from around the tank were excavated down to a concrete pad underlying it. On the east and north sides of the tank, soils were excavated to the fence at the perimeter of the high voltage substation and on the south side, to the foundation of Building 40. Based on site conditions, the NYSDEC inspector approved backfilling the excavation with clean soils. Additional excavation was deemed unnecessary and impractical. In January 1992, a new 9,000-gallon, aboveground tank was installed, complete with secondary containment.

Building 30 SWMU. On February 25, 1994, GE Fort Edward site personnel verified the existence of a subgrade concrete vault in Building 30 which contained numerous small PCB capacitors. The NYSDEC and U.S. EPA were notified of this finding on February 25, 1994. Between February 28 and March 2, 1994, the capacitors were removed from the vault and the concrete walls and floor were scrubbed with an alkaline cleaner and rinsed with high pressure water. The capacitors were subsequently incinerated at the Chemical Waste Management facility in Port Arthur, Texas. Upon completion of the cleaning activity, the vault was inspected for structural integrity. The vault appeared to be structurally intact. Cracks or other evidence of failure were not visible. Six wipe samples from the interior of the vault were collected. The results of the wipe sampling indicated that PCBs were present on the surface of the concrete. The depth of penetration into the concrete is unknown. A report describing activities associated with the Building 30 vault was prepared by O'Brien & Gere and submitted to NYSDEC on March 25, 1994 (O'Brien & Gere, 1994a).

Foil Mill AOC. Based on the discovery of a floating oil product in a 20-inch vertical VCP near the southwest corner of Building 40 and the infiltration of oil/water in the small basement area at the southeast corner of Building 40, GE prepared an "area of concern" (AOC) assessment report. The report was prepared and submitted to NYSDEC on May 4, 1994 (O'Brien & Gere 1994b). Analysis of samples collected from both locations identified the oil samples as kerosene. Total PCB concentrations of 140 mg/kg were reported for the oil samples from both locations. Clean Harbors, Inc. was mobilized to the plant on March 14, 1994 and removed the small amount of oil from the concrete basement floor and subsequently washed the floor with penetone. Following the washing, wipe samples were collected for PCB analysis. Results for each analysis was less than 5 ug/100 cm^2. The cracks in the floor were also grouted to seal these openings.

2. Site background

2.1. Site location

The study area is the GE Fort Edward plant located approximately 800 feet east of the Hudson River between the Villages of Hudson Falls to the north, and Fort Edward to the south. The facility is approximately 32 acres and bounded on the east by Broadway, on the south by Park Avenue and the Delaware & Hudson Railroad/Allen Street on the west as shown on Figure 2-1. As shown on Figure 2-1, an approximately 200 foot wide parcel located between Allen Street and the Hudson River is also owned by GE and is part of the study area.

2.2. Brief site history

Reportedly, the Fort Edward plant has been in operation since 1942. Between 1942 and 1946 selsyn motors were manufactured for the U.S. Department of Defense; since 1946 the plant has produced small industrial capacitors. Operations related to capacitor production have included aluminum rolling, tin plating, capacitor recovery and salvage operations, polypropylene film manufacture, refining and blending of dielectric fluids, and quality control operations. Various cleaning operations to remove residues resulting from fabrication have also been conducted at the site. Among the products used in various operations were PCBs, chlorinated and non-chlorinated organic solvents, and kerosene. PCB use as a dielectric fluid at the site was discontinued in 1977. The plant has eliminated its use of organic solvents in recent years by modifying processes, installing new state-of-the-art processes, and implementing waste minimization programs.

Present facilities on the Fort Edward plant consist of several buildings, a concrete basin on the southwest corner of the property, and parking areas. The largest building is subdivided into four sections as follows: (1) original manufacturing building (Bldg. 23), (2) addition to manufacturing building (Bldg. 23 ext.), (3) warehouse (Bldg. 23-A), and (4) capacitor plant expansion (Bldg. 23-B). Building 23-A was subsequently expanded to include a finished goods warehouse (Bldg. 26) and a maintenance and waste storage building (Bldg. 31). The second building, the former aluminum rolling mill (Bldg. 40), has been expanded several times since its original construction. Smaller buildings on the site include a pump house, a maintenance building, and the wastewater treatment facility. Rolling mill operations were terminated in 1995 and assembly and testing operations from the Hudson Falls facility were moved to Building 40.

Prior to construction of the existing wastewater treatment facility in 1976, storm water and in-plant wastewater converged at a manhole (MH-4) located directly west of the southwest corner of the current Foil Mill. Wastewater was discharged from MH-4 directly to the Hudson River through a 30-inch vitrified clay pipe (VCP).

Sanitary wastes prior to 1976 from the Foil Mill and the Main Plant were directed to a lift station located approximately 90 feet south of the Foil Mill and sent to an on-site septic tank/leach field system. Sanitary wastes generated at the guard house and Building 23-A (warehouse) were sent to separate septic systems.

Modifications to the GE Fort Edward wastewater management system were primarily completed in 1976 and 1977 and included the replacement and rerouting of wastewater to a newly constructed wastewater collection/treatment system. A 40,000 gallon per day (gpd or gal/day) extended aeration system was installed to treat sanitary wastes generated at the site. A 1.8 million gallon concrete equalization basin was constructed in the southwest corner of the site. Site wastewater (including treated sanitary effluent) and storm water were directed to the basin, treated at the newly constructed site treatment plant and discharged pursuant to a SPDES permit to the Hudson River through a new 6-inch line.

Since 1976 numerous improvements, investigations and remedial actions have been undertaken by GE at the Fort Edward plant to reduce the potential impact of the site on the surrounding community. These actions are described in Section 1.4.

2.3. Remedial investigation summary

The Fort Edward RI was successful in satisfying the RI obligations of Order on Consent #A5-0316-94-06 and meeting the project objectives of evaluating impacts, if any, of chemicals that may have previously migrated off-site on human health and the environment; determining if contamination continues to migrate off-site; implementing interim remedial measures (IRMs) as necessary; gathering engineering data required to perform a feasibility study; and to further satisfy corrective action obligations pursuant to the Solid Waste Disposal Act as amended by the Resource Conservation and Recovery Act and the Hazardous and Solid Waste Amendments and the New York ECL Article 27, Title 9. The results of the RI are summarized in the remainder of this Section. These results are presented in detail in the RI report (O'Brien & Gere, 1997).

2.3.1. Geology

The GE Fort Edward Plant is located in the Hudson-Champlain lowland physiographic province of New York. This lowland is a broad depression formed by erosion of soft shales and limestones of early paleozoic age, by the preglacial and interglacial Hudson River and by glacial scour during the Pleistocene. The region is characterized by open, sparsely wooded, flatlands with relatively low relief.

With the exception of fill, unconsolidated deposits of glacial origin unconformably overlie the bedrock throughout much of the Fort Edward Plant area. The glacial deposits are associated with the Hudson-Champlain Lobe of the late Wisconsin Laurentide ice sheet. Five types of unconsolidated sediments have been identified at the site. These include glacial till, glacio-lacustrine silt and clay, a transitional zone, glacio-deltaic sand and gravel and artificial fill. The unconsolidated deposits are underlain by the Snake Hill Formation.

Glacial till observed directly overlying bedrock at the site is composed of a poorly sorted mixture of sand, gravel, and sometimes cobbles in a matrix of fine sand and silt with occasional clay seams. The glacial till unit is absent in the area around the equalization basin, located in the southwestern portion of the site, where it appears to have been removed during the excavation activities associated with the construction of the basin.

Glacio-lacustrine silt and clay deposits are generally observed overlying the glacial till unit. The glacio-lacustrine silt and clay unit ranges in thickness from 44.9 feet in the northeast corner of the site adjacent to Upper Broadway and thins out to zero feet in the vicinity of the Foil Mill, the area of the former leachfield and the equalization basin where little to no glacio-lacustrine silt and clay unit is observed.

The glacio-lacustrine silt and clay unit can best be described as dark grey silt and clay, with frequent clayey silt seams and occasional fine sand partings. Descriptions range from a dark grey to brown varved silty clay to grey clayey silt, with frequent silt and clay seams and fine sand partings.

Generally this unit is brown to red at the top and gradually changes to grey over the top 1 to 2 feet of the unit.

Overlying the glacio-lacustrine silt and clay unit in the eastern and southeastern portions of the site is a sequence of light gray sand and silt interbedded with frequent seams and partings of clay and silt which become more frequent with depth. This zone has been designated the transition zone and represents a change in depositional environment from a deep water , low energy glacial lake environment to a higher energy, near shore environment.

The uppermost unconsolidated unit at the Fort Edward plant is a glacio-deltaic sand and gravel unit and is ubiquitous throughout the site and is best described as brown coarse to fine sand with a little fine gravel. The glacio-deltaic sand and gravel unit is thinnest in the western portion of the site in the vicinity of the Foil Mill. This unit thickens considerably to the east and is observed at a thickness of 28.4 feet along the eastern property boundary of the site. The thickest accumulation of the sand and gravel unit is observed south of the plant site with an observed thickness of 42.9 feet at well location OBG-61, located near Griffin Avenue.

The bedrock immediately underlying the unconsolidated deposits in the vicinity of the Fort Edward plant are the shales of the Middle Ordovician Snake Hill Formation.

The Snake Hill Formation is the highest and youngest formation encountered in the study area. Based on the results of the rock core from well OBG-26BD, the geophysical log from former production well PW-1 and investigations being performed in the Hudson Falls area, the Snake Hill Formation has been differentiated into three distinct units, these are the Upper, Middle and Lower Snake Hill Shale. The Upper Snake Hill Formation consists of approximately 200 feet of dark grey to black, fine grained, massive to moderately jointed shale. The Snake Hill shale is underlain by the Glens Falls limestone and the Beekmantown Group.

2.3.2. Hydrogeology

A conceptualization of the hydrogeologic system at the Fort Edward facility has been developed based on information obtained during various investigations performed at the facility and includes four hydrogeologic units: the shallow unconsolidated unit, the transition zone unit, the low permeability confining unit and the shallow bedrock unit.

The shallow unconsolidated unit is composed of glacio-deltaic sand. The water table generally occurs in this unit under unconfined conditions and is free to rise and fall in response to ground water recharge and discharge.

The transition zone hydrogeologic unit lies stratigraphically between the shallow unconsolidated unit and the shallow bedrock unit. The transition zone is limited in its extent across the site and is only found in the eastern portion of the site. This unit is less permeable than the overlying unconsolidated hydrogeologic unit. The mean horizontal hydraulic conductivity for the transition zone hydrogeologic unit is calculated to be 6.37×10^{-4} cm/sec (1.81 ft/day).

The shallow unconsolidated unit and the transition zone is generally hydraulically separated from the shallow bedrock unit by a low permeability till and clay-rich aquitard. The results of the hydraulic conductivity tests performed in the till zone well OBG-26T indicate that the till unit has a hydraulic conductivity of 3.04×10^{-6} cm/sec (.0086 ft/day).

The shallow bedrock hydrogeologic unit is composed of black, dense shale of the Snake Hill Formation. With the exception of well OBG-46BS, ground water in the shallow bedrock hydrogeologic unit is generally observed under confined conditions at the Fort Edward facility. At well location OBG-46, the confining layer is missing and the ground water in the bedrock is in direct contact vertically with the atmosphere through open pore spaces in the shallow unconsolidated unit and is best described as unconfined.

Ground water flow within the shallow bedrock hydrogeologic unit occurs principally through secondary porosity features such as fractures, joints and bedding planes. The mean hydraulic conductivity for the shallow bedrock hydrogeologic unit is 5.86×10^{-5} cm/sec (0.17 ft/day).

Ground water flow within the shallow unconsolidated unit at the facility is controlled by a ground water table divide which trends northeast to southwest between monitoring well location OBG-54 and GM-5. Ground water flow in the northwest, western and southwestern portion of the facility is generally to the west towards the Hudson River. Flow in the central and southeastern portion of the facility is generally to the southeast toward Park Avenue.

As a result of pumping, ground water flow in the shallow unconsolidated unit has been altered in the southeastern portion of the facility. A trough of depression, has been formed in the vicinity of the shallow ground water recovery system. Water levels have been drawn down in the area between recovery well RW-3 and monitoring well GM-29 and indicate that ground water immediately south of Park Avenue is being pulled back (i.e., north) toward the shallow ground water recovery system.

Ground water flow within the shallow unconsolidated unit in the area south of Park Avenue is generally to the south. Ground water flow in the central portion of the off-site ground water plume (i.e., areas west of Putnam Avenue and Ethan Allen) is generally to the south and shifts toward the southwest in the area west of Broadway, south of well OBG-60.

Ground water flow within the transition zone is principally horizontal through the fine sand and silt layers and seams within this unit. Based on ground water levels measured during pumping of the shallow unconsolidated unit ground water recovery system, ground water flow in the transition zone is from northeast to southwest toward the ground water recovery wells.

Ground water flow in the shallow bedrock is controlled by a hydrogeologic divide which trends north-northwest to the south-southeast in the vicinity of Lower Allen Street. Ground water flow in the area west of Lower Allen Street is generally to the west towards the Hudson River. In the area east of Lower Allen Street ground water in the shallow bedrock flows west to east across the facility. Ground water flow directions and hydraulic gradients do not appear to change appreciably from high to low recharge conditions within the shallow bedrock unit.

The effect of ground water pumping from recovery wells GM-8DR and GM-11D is observed in the southwestern portion of the facility. Water levels have been drawn down in the immediate vicinity of these two wells and indicates that ground water immediately east of pumping well GM-11D is being pulled back (i.e., west) toward the pumping well.

Ground water flow in the area east of Lower Allen Street, intermediate bedrock ground water in the southeast portion of the facility flows west to east across the facility.

The effect of ground water pumping from recovery wells GM-8DR and GM-11D is observed in the intermediate bedrock in the southwestern portion of the facility. Water levels have been drawn down significantly and indicate that ground water immediately east of pumping wells GM-11D and GM-8DR is being pulled back (i.e., west) toward the pumping wells.

Ground water flow within the deep bedrock is controlled by a hydrogeologic divide which trends north to south between well OBG-15BD through the area of the Foil Mill towards well location OBG-26. Ground water flow in the western portion of the facility and west of Lower Allen Street is generally to the west towards the Hudson River. Ground water in the central and eastern portion of the facility flows west to east across the facility towards Upper Broadway. Ground water flow directions and hydraulic gradients do not change appreciably from high to low recharge conditions within the shallow bedrock unit.

2.3.3. Constituents in ground water

Ground water samples were collected from a total of 106 monitoring wells located on-site, and 22 monitoring wells and four springs located off-site.

Building 40 area. Concentrations of one or more VOCs characteristic of kerosene were detected above the NYSDEC Class GA ground water standards or guidance values in monitoring wells GM-5, OBG-50, OBG-52, OBG-55, and OBG-68 and ranged in total concentrations from 11 to 1,250 μg/L.

Concentrations of chlorinated VOCs, 1,1-dichloroethane and/or 1,1,1-trichloroethane, were detected at or above NYSDEC Class GA ground water standards (5 μg/L each) in monitoring wells OBG-55 and OBG-68 and ranged in total concentrations from 5 to an estimated 1,310 μg/L.

Concentrations of Aroclor-1242 and/or Aroclor-1254 were detected above NYSDEC Class GA ground water standard of 0.10 μg/L in monitoring wells F-2, F-3, GM-2, GM-5, OBG-44S (destroyed), OBG-48S (destroyed), OBG-50, OBG-51, OBG-52, OBG-53, OBG-1A(replaced GM-1), OBG-54 and OBG-68 and ranged in total concentrations of 0.12 to 60 μg/L.

Concentrations of one or more VOCs characteristic of kerosene were detected above NYSDEC Class GA ground water standards or guidance values in monitoring wells FM-1, FM-5, FM-7, FM-9, FM-10, FM-11, and FM-12 and ranged in total concentration from 63 to 251 μg/L.

Concentrations of chloroethane, 1,1-dichloroethane, cis-1,2-dichloroethene, and 1,1,1-trichloroethane were detected above NYSDEC Class GA ground water standards in monitoring wells FM-9 and FM-11 and ranged in total concentration from 216 to 1,521 μg/L.

Concentrations of Aroclor-1242 and/or Aroclor-1254 were detected above the NYSDEC Class GA ground water standard of 0.10 μg/L in each of the 10 wells and ranged in total concentration of 0.264 to 310 μg/L. Additionally, Aroclor-1242 was detected at concentrations of 4.4 and 220 mg/L in the light non-aqueous phase liquid (LNAPL) samples collected from monitoring wells FM-5 and FM-12, respectively.

Leachfield. One shallow unconsolidated unit monitoring well, OBG-83, was installed in the leachfield area as part of the Supplemental RI scope of work. VOCs were not detected in the ground water sample collected from this well during the supplemental RI sampling event. Aroclor-1242 was detected at an estimated concentration of 0.059 μg/L, below the Class GA ground water standard of 0.10 μg/L.

Eastern property boundary. No VOCs or PCBs were detected in monitoring well OBG-42S, located on the northeastern property boundary.

Transition zone. Trichloroethene was the most frequently detected VOC in the transition zone wells. The next most frequently detected VOCs included cis-1,2-dichloroethene, benzene, and chloroform. Concentrations of trichloroethene and/or cis-1,2-dichloroethene were detected above NYSDEC Class GA ground water standards (5 μg/L each) in on-site transition zone wells OBG-63, OBG-64, and OBG-82 and ranged in total concentrations from 8 to 4,300 μg/L. Trichloroethene was detected above the NYSDEC Class GA ground water standard of 5 μg/L at concentrations of 29 and 30 μg/L in one off-site transition zone well, OBG-76, located in the area of the off-site overburden plume south of the facility.

Aroclor-1242 and/or Aroclor-1254 were detected above the NYSDEC Class GA ground water standard of 0.10 μg/L in one off-site well, OBG-76, at 0.39μg/L and five on-site wells, OBG-63, OBG-64, OBG-65, OBG-66, and OBG-82, and ranged in total concentration from 2.0 to 28.1 μg/L. Aroclor-1242 was detected in off-site well OBG-79 at an estimated concentration of 0.055 μg/L, well below the ground water standard of 0.10 μg/L.

Southern portion of the facility. Twenty-five (25) shallow unconsolidated unit monitoring wells are located within the southern portion of the facility.

Trichloroethene and cis-1,2-dichloroethene were the most frequently detected VOCs in the shallow unconsolidated unit ground water collected from the southern portion of the facility. The other less frequently detected VOCs include tetrachloroethene, vinyl chloride, 1,1,1-trichloroethane, 1,1-dichloroethane, chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, benzene, chloroform, and methylene chloride.

Concentrations of one or more chlorinated VOCs were detected at or above NYSDEC Class GA ground water standards in shallow unconsolidated unit monitoring wells GM-8A, GM-12A, GM-12B, GM-12C, GM-21, GM-22, GM-23, GM-24, GM-25, GM-30, GM-32, GM-33, and GM-35 and ranged in total concentrations of 5 to 10,000 μg/L.

Concentrations of several chlorobenzenes were reported above NYSDEC Class GA ground water standards in shallow unconsolidated unit monitoring wells GM-8A, OBG-8B (formerly GM-8A), and GM-25 and ranged in total concentrations of 139 to 723 μg/L.

Concentrations of Aroclor-1242 and/or Aroclor-1254 were detected at or above the NYSDEC Class GA ground water standard of 0.10 μg/L in GM-8A, OBG-8B (GM-8A replacement), GM-12A, GM-12B, GM-12C, GM-21, GM-22, GM-24, GM-25, GM-28, GM-30, GM-32, GM-33, GM-35, OBG-26T(till zone), and OBG-56 and ranged in concentration from 0.10 to 77 μg/L. It should be noted that PCBs were not confirmed in OBG-56 in January or June 1996.

Concentrations of Aroclor-1242 and/or Aroclor-1254 were reported below the NYSDEC Class GA ground water standard in GM-11, GM-16, GM-29, and GM-31, ranging from an estimated 0.055 to 0.093 μg/L.

Off-site. Shallow unconsolidated unit ground water monitoring wells and springs located off-site include 18 wells and springs.

Trichloroethene and cis-1,2-dichloroethene were the most frequently detected VOCs in shallow unconsolidated unit ground water samples collected off-site. The other VOCs detected include chloroform and bromodichloromethane. Concentrations of trichloroethene and/or cis-1,2-dichloroethene were detected above NYSDEC Class GA ground water standards (5 μg/L each) in off-site monitoring locations SW-3, SW-4, SW-5, GFNB, Dobroski, Griffin Avenue spring, Hillview Avenue spring, OBG-59, and OBG-61 and ranged in total concentrations from 8 to 3,920 μg/L.

Chloroform was detected at estimated concentrations of 25 and 14 μg/L in the samples collected from off-site well OBG-59 in the October/November 1995 and June 1996, respectively. These concentrations of chloroform are above the NYSDEC Class GA ground water standard of 7 μg/L.

Aroclor-1242 and/or Aroclor-1254 were reported above NYSDEC Class GA ground water standard of 0.10 μg/L in monitoring wells SW-3, SW-4, GFNB, OBG-57, and Rencor #2, ranging from total concentrations of 0.14 to 1.9 μg/L. However, concentrations of PCBs in OBG-57 located on the Rencor property have shown a decrease since January 1995 and PCBs were not detected in Rencor #2 in June 1996.

Bedrock ground water. With the exception of ground water recovery wells GM-11D and GM-8DR and monitoring well GM-9D, no bedrock wells exhibited confirmed detections of VOC or PCB levels above NYSDEC Class GA ground water standards.

3. Development of alternatives

This section describes the process was been used to develop a range of remedial alternatives for the site. This process included assembling combinations of technologies into alternatives that are potentially applicable to the site, and included the following components:

- development of remedial action objectives
- development of general response actions
- identification of volumes or areas of affected environmental media
- identification and screening of remedial technologies and process options
- evaluation of process options
- assembly of alternatives

The results of the alternative development process are presented in this section. The alternatives are evaluated individually and comparatively in Section 5.

3.1. Remedial action objectives

Remedial action objectives (RAOs) are specific goals that are established to adequately protect human health and the environment. They specify the contaminant(s) of concern, the exposure route(s), receptor(s), and acceptable contaminant level(s) for each exposure route. These objectives are typically based on ARARs, or risk-based levels established by a risk assessment.

Section 121(d) of CERCLA, as amended by SARA, requires that remedial actions comply with ARARs under federal or state environmental law at the completion of remedial action. Three categories of ARARs are required to be considered: chemical-specific, location-specific, and action-specific.

- Chemical-specific ARARs are health-based or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values. These numerical values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment.

- Location-specific ARARs set restrictions on activities based on the characteristics of the site or its immediate environs.

- Action-specific ARARs set controls or restrictions on particular types of remedial actions once the remedial actions have been identified as part of a remedial alternative.

Chemical-specific and location-specific ARARs are considered during formulation of the RAOs. Action-specific ARARs are considered after the remedial alternatives are developed, as the actions proposed in each alternative may require compliance with additional ARARs. ARARs, including action-specific ARARs that are potentially applicable are described in more detail in Section 4.

The chemical-specific ARARs that have been identified as potentially applicable to the site are the New York State Class GA Ambient Ground Water Quality Standards in 6 KNOCKER Part 703. No location-specific ARARs have been identified.

These ARARs have been taken into consideration during development of the following RAOs for this project:

- prevent, to the extent practicable, ingestion of ground water affected by the site that does not attain NYSDEC Class GA Ambient Water Quality Criteria
- prevent, to the extent practicable, off-site migration of ground water that does not attain NYSDEC Class GA Ambient Water Quality Criteria
- prevent, to the extent practicable, migration of LNAPL and DNAPL off the site

Other goals of the project, although not specifically RAOs, include:

- satisfy corrective action obligations pursuant to the facility's RCRA Part 373 permit for SWMUs, as described in the approved RI/FS work plan
- continue on-going remedial actions to address ground water in the southern ground water plume

These RAOs focus on the potential ground water exposure route. Soil has not been identified as posing an unacceptable risk in the risk assessment (O'Brien & Gere, 1997). Most of the site is covered by structures or pavement, which minimizes direct contact with underlying soil that may contain PCBs or VOCs.

Furthermore, it is not considered to be practical to perform large scale soil removal and/or treatment actions at the site due to the following conditions:

- several sources of PCBs and VOCs exist at the site, which have resulted in the distribution of PCBs and VOCs in soil and/or ground water across a large portion of the site
- a large portion of the source areas extends beneath structures which house active manufacturing operations, limiting accessibility
- the most significant source area (DNAPL plume) is approximately 30 ft underground, 10 to 15 ft below the water table
- most of the source areas contain PCBs, which are not typically amenable to *in situ* treatment technologies
- most of the soil containing PCBs/VOCs is beneath impervious surfaces (manufacturing buildings or pavement) which limit infiltration
- the existing ground water collection and treatment system has been demonstrated to be effective on the southern ground water plume
- collection and management of ground water will eventually reduce the concentrations of PCBs/VOCs in soil

Therefore, based on these conditions, and as an unacceptable risk to human health from soil at the site was not identified in the risk assessment, soil containing PCBs or VOCs will not be considered in this FS beyond the extent required to achieve the RAOs described above.

3.2. General response actions

General response actions are medium-specific actions that may be combined into alternatives to satisfy the remedial action objectives. Two media have been addressed in this FS. These media include ground water, LNAPL, and DNAPL. As DNAPL collection was expected to be a significant component of several remedial alternatives developed for the site, a separate evaluation of potential methods of DNAPL collection has been performed. The results of this evaluation are presented in Appendix A. The DNAPL collection method recommended in Appendix A has been incorporated into the remedial alternatives described in Section 3.6. As described in Section 3.1, soil is not being addressed specifically in this FS; however, it is anticipated that some soil removal and management may be required as part of the implementation of some of the remedial alternatives. Therefore, the general response actions presented below focus on ground water, LNAPL, DNAPL, and soil (generated as a result of excavation for implementation of other actions). These general response actions are:

- institutional actions
- containment actions
- collection actions
- collection enhancement actions
- disposal actions
- treatment actions.

3.3. Volumes and areas of media

The results of field activities performed during the RI at the Fort Edward facility are described in detail in the Fort Edward Remedial Investigation Report (O'Brien & Gere, January 1997). The field activities included the collection of ground water and surface water for laboratory analyses of PCBs, VOCs, and semi-volatile organic compounds (SVOCs) for evaluating the impacts, if any, of chemical substances that may have previously migrated off-site on human health and the environment; addressing whether contamination continues to migrate off-site; and, satisfying corrective action obligations pursuant to the Solid Waste Disposal Act as amended by the RCRA and Hazardous and Solid Waste Amendments and the New York ECL Article 27, Title 9.

A summary of the analytical data, volumes and area of media, and the remedial alternatives is discussed in the following sections by potential source areas. The basis for estimating the areal extent and volume of PCB, VOC, and/or SVOC-containing ground water which have a potential human health or environmental impact include the following criteria:

- ground water standards for ground water utilized as a source of drinking water (i.e., Class GA) developed by the NYSDEC Division of Water under 6 KNOCKER Part 703.

3.3.1. Ground water

As described in detail in the Fort Edward Remedial Investigation Report (O'Brien & Gere, January 1997), ground water samples were collected from on-site and off-site monitoring wells, on-site inactive storm sewers, and off-site springs during the RI sampling events from October 30, 1995 through October 4, 1996. The results of the RI ground water sampling efforts are discussed below by potential source areas A, B, C, E, and F, which are outlined below.

- Area A is located north of Building 40 and includes seven shallow unconsolidated monitoring wells;
- Area B is located in the vicinity of Building 40 and includes 34 shallow unconsolidated monitoring wells;
- Area C is located in the southern portion of the facility and includes 33 shallow unconsolidated monitoring wells. Area C also includes two inactive manholes. Area C is also located off-site and includes 22 monitoring wells and four springs;
- Area E is located throughout the facility and includes 31 bedrock monitoring wells; and,
- Area F is located in the former leachfield area and includes one shallow unconsolidated monitoring well.

As discussed in detail below, shallow unconsolidated and/or bedrock ground water has been impacted by VOCs and/or PCBs. The specific VOCs and PCBs identified and the concentrations detected in each of the monitoring wells and springs included in the RI sampling events are included in the Fort Edward Remedial Investigation Report (O'Brien & Gere, 1997). The concentrations of organic compounds which exceed the Class GA ground water standards or guidance values developed by NYSDEC, if any, are also discussed below.

3.3.1.1. Area A

Area A is located north of Building 40 and includes the area within monitoring well F-4 north to monitoring wells GM-38, GM-39 and OBG-15 cluster (Figure 2-1). No VOCs or PCBs were detected at quantifiable concentrations in the shallow unconsolidated ground water samples collected from this area. The results of the RI ground water sampling efforts indicate that one of the shallow ground water wells in this area has been impacted by PCBs.

3.3.1.2. Area B

Area B includes the area within monitoring wells OBG-48S and OBG-45S to the west, monitoring wells OBG-54 and OBG-68 to the north, GM-9 and OBG-52 to the east and monitoring wells OBG-62, F-2 and OBG-51 to the south (Figure 2-1).

One or more VOCs characteristic of kerosene were detected at concentrations above the Class GA ground water standards or guidance values in five monitoring wells GM-5, OBG-50, OBG-52, OBG-55, and OBG-68 and ranged in total concentrations from 11 to 1,250 μg/L. In addition, chlorinated VOCs (i.e., 1,1-dichloroethane and 1,1,1-trichloroethane) were detected at or above Class GA ground water standards in monitoring wells OBG-55 and OBG-68 and ranged in total chlorinated VOC concentrations from 5 to an estimated 1,310 μg/L.

Two SVOCs characteristic of kerosene (i.e., naphthalene and 2-methylnaphthalene) were detected at concentrations ranging from 54 to 83 μg/L, greater than the Class GA ground water guidance value for naphthalene in monitoring well GM-5.

Aroclor-1242 and/or Aroclor-1254 were detected above the Class GA ground water standard of 0.10 μg/L in monitoring wells F-2, F-3, GM-2, GM-5, OBG-44S(destroyed), OBG-48S(destroyed), OBG-50, OBG-51, OBG-52, OBG-53, OBG-54, OBG-1A, and OBG-68 and ranged in total concentration from 0.12 to 60 μg/L.

Based on the results of the RI, the volume of ground water available for recovery through a ground water collection trench around the west and south sides of the Foil Mill is estimated to be about 35 gpm. Actual discharge to the trench will vary seasonally depending upon ground water elevations in the vicinity of the Foil Mill and may decline with time.

3.3.1.3. Area C

Area C is located in the southern portion of the facility. This area on-site includes the area within monitoring wells GM-14, GM-11, and GM-7 to the west; monitoring wells OBG-83, GM-19, and OBG-80 to the north; OBG-81 and OBG-66 to the east; and monitoring wells OBG-56, GM-16 and OBG-65 to the south (Figure 2-1). The inactive manholes in this area include MH-23 and MH-25. Area C off-site includes the area encompassing the Dobroski well, monitoring well OBG-85, the Griffin Avenue spring and Hillview Avenue spring to the west, monitoring wells

OBG-84 and OBG-76 to the south, monitoring wells OBG-77, OBG-58, and Hughes to the east, and springs # 1 and #3 to the south.

Chlorinated VOCs (e.g., trichloroethene and cis-1,2-dichloroethene) were detected at concentrations above Class GA ground water standards in on-site monitoring wells GM-8A, GM-12A, GM-12B, GM-12C, GM-21, GM-22, GM-23, GM-24, GM-25, GM-30, GM-32, GM-33, GM-35, OBG-63, OBG-64, and OBG-82 and ranged in total concentrations from 5 to 10,000 μg/L. In addition, several chlorobenzenes were reported above Class GA ground water standards in shallow unconsolidated unit monitoring wells GM-8A and GM-25 ranging in total concentrations from 139 to 723 μg/L.

VOCs characteristic of kerosene were detected at concentrations above Class GA ground water standards in the ground water collected from inactive storm sewer manhole MH-23.

Chlorinated VOCs (i.e., trichloroethene and cis-1,2-dichloroethene) were detected at concentrations above Class GA ground water standards in off-site monitoring locations SW-3, SW-4, SW-5, GFNB, Dobroski, Griffin Avenue spring, Hillview Avenue spring, OBG-59, OBG-61, and OBG-76 and ranged in total concentrations from 8 to 3,920 μg/L.

Aroclor-1242 and/or Aroclor-1254 were detected at concentrations at or above the Class GA ground water standard of 0.10 μg/L in on-site wells GM-8A, OBG-8B (formerly GM-8A), GM-12A, GM-12B, GM-12C, GM-21, GM-22, GM-24, GM-25, GM-28, GM-30, GM-32, GM-33, GM-35, OBG-26T, OBG-56, OBG-63, OBG-64, OBG-65, OBG-66, and OBG-82 and ranged in total concentrations from 0.10 to 77.0 μg/L.

Aroclor-1242 and/or Aroclor-1254 were detected at concentrations above the Class GA ground water standard of 0.10 μg/L in the ground water collected from the inactive storm sewer manholes MH-23 and MH-25 and ranged in total concentrations from 9.7 to 1,200 μg/L. In addition, the LNAPL sample collected from manhole MH-23 contained Aroclor-1242 (78,000μg/L) and Aroclor-1254 (24,000 μg/L) concentrations which exceeded the Class GA ground water standard.

Aroclor-1242 and/or Aroclor-1254 were detected at concentrations above the Class GA ground water standard of 0.10μg/L in off-site monitoring wells SW-3, SW-4, GFNB, OBG-57, OBG-76 and Rencor #2 and ranged in total concentrations from 0.14 to 1.9 μg/L. It should be noted that concentrations of PCBs in OBG-57, located on the Rencor property have shown a decrease since January 1995 and PCBs were not detected in Rencor #2 in June 1996.

Contaminated ground water within the on-site portion of Area C generally flows to the southeast towards Park Avenue and the shallow unconsolidated unit ground water recovery system. Based on the results of the RI and previous investigations, the shallow unconsolidated unit ground water recovery system is an effective hydraulic barrier, preventing further migration of contaminated ground water to the south. Ground water discharge to the shallow unconsolidated unit ground water recovery system is about 70 gpm based on flow measurements recorded during the 1996 calendar year. Contaminated ground water in the off-site portion of Area C is discharged to off-site ground water recovery well RW-2 at an effective average flow rate of approximately 8.2 gpm, based on flow measurements recorded during the 1996 calendar year.

In addition to ground water flow within the shallow unconsolidated unit, contaminated ground water has been observed within the transition zone. The potential contaminated ground water discharge from the transition zone is estimated to be about 12 gpm.

3.3.1.4. Area E

Area E is located throughout the facility and includes 31 bedrock monitoring wells (Figure 2-1).

Miscellaneous VOCs (i.e., benzene and chloroform) were detected in seven of the 14 shallow bedrock monitoring wells; GM-9D, OBG-74BS, OBG-43BS, OBG-47BS, OBG-49BS, OBG-72BS, and OBG-75BS. The concentrations of chloroform (ranging 1 to 7 μg/L) were detected at or below the Class GA ground water standard of 7.0 μg/L. Benzene was detected at concentrations above the Class GA ground water standard of 0.7 μg/L in monitoring wells GM-9D and OBG-74BS (6 to 11 μg/L). However, the benzene detected at 6 μg/L in well GM-9D was not confirmed in the following two sampling events.

Chlorinated VOCs were detected at concentrations above Class GA ground water standards in intermediate bedrock unit recovery wells GM-8DR and GM-11D and ranged in total concentrations from 17 to 20 μg/L. No VOCs were detected in the deep bedrock monitoring wells.

With the exception of ground water recovery wells GM-11D and GM-8DR, and monitoring well GM-9D, no bedrock wells exhibited confirmed detections of VOCs or PCBs at concentrations above NYSDEC Class GA ground water standards.

Aroclor-1242 was detected at concentrations above Class GA ground water standard of 0.10 μg/L in wells GM-8DR and GM-11D and ranged from 36 to 76 μg/L. No PCBs were detected above the Class GA ground water standard of 0.10 μg/L in the deep bedrock monitoring wells.

The contaminated ground water discharge rate from the shallow bedrock in the vicinity of recovery wells GM-8DR and GM-11D is about 2.5 gpm based on flow measurements recorded at bedrock recovery wells GM-8DR and GM-11D during the 1996 calendar year.

3.3.1.5. Area F

Area F includes the former leachfield area and includes one monitoring well OBG-83 (Figure 2-1). No VOCs were detected at quantifiable concentrations in the shallow unconsolidated ground water sample collected from this area. No PCBs were detected above the Class GA ground water standard concentration of 0.10 ug/L.

3.3.2. DNAPL

Based on the observations from 74 soil borings drilled as part of the Remedial Investigation, it appears that the likely source of the DNAPL at the site was the rail car off-loading area and bulk storage tank farm area located adjacent to the CCO Treat Area in Building 23 (Appendix A, Figure A-1). The DNAPL has generally migrated south/southeast. Currently, the approximate dimensions of the recoverable (pooled) area of the DNAPL plume are 110 by 230 feet. Although the surface of the low permeability layer varies in elevation, boring log data indicates the approximate thickness of DNAPL is 2.5 ft. Assuming a porosity of 30%, the approximate volume of DNAPL within the void space of the soil within this area is 142,000 gallons. Assuming that the estimated DNAPL retention capacity of the site soil (the amount of DNAPL that will remain adsorbed to the aquifer material as unrecoverable residual DNAPL) is 20% (Appendix A; Cohen and Mercer 1993), the estimated recoverable volume of DNAPL is approximately 114,000 gallons.

3.4. Identification and screening of remedial technologies and process options

This step requires identification of potentially applicable remedial technology types and process options for each general response action. Process options were screened on the basis of technical implementability.

The technical implementability of the identified process options was evaluated with respect to site contaminant information, site physical characteristics, and areas and volumes of affected media.

A summary of the screening of technologies and process options is presented in Table 3-1. A discussion of the remedial technology process options that were considered to be potentially applicable after screening follows:

Institutional actions
Land use restrictions. Land use restrictions would preclude the conduct of activities that could potentially impair the integrity of a remedy without prior review and approval by NYSDEC.

Fencing. Fencing would consist of the placement and maintenance of fencing to limit access and thereby minimize contact with contaminated materials. The GE Fort Edward facility is already surrounded by fencing; however, additional fencing around the off-site springs may be considered.

Sign posting. Signs indicating the presence of PCBs and/or VOCs in soil or surface water (springs) could be posted to discourage contact by humans.

Monitoring. Collection of ground water samples from, and adjacent to, the GE Fort Edward facility could be performed to monitor PCB and/or VOC concentrations in ground water.

Alternate water supply. Providing residents who use ground water in the vicinity of the site with an alternate water supply is an effective method to prevent ingestion of ground water affected by the site. GE has already implemented a program to supply municipal water to residents.

Containment actions
Flow diversion. Flow diversion would involve the use of a physical or hydraulic barrier to reduce ground water and/or LNAPL/DNAPL flow through the site, or control ground water and/or LNAPL/DNAPL flow off-site. Flow diversion may be accomplished by collection wells or vertical barriers, such as slurry walls, sheet piling, vibrated beam walls, auger mix walls or jet grout walls.

Collection actions
Extraction. Extraction of ground water and/or LNAPL/DNAPL may be accomplished by installation of vertical or horizontal wells, pumping and management of collected ground water.

Interception. Ground water and/or LNAPL/DNAPL may be intercepted by installation of an interception trench with collection of ground water and/or LNAPL/DNAPL from within the trench and subsequent management of collected ground water.

Collection enhancement actions
Collection of LNAPL/DNAPL may be enhanced thermally or by injection of agents such as surfactants or solvents.

Disposal actions
Disposal actions are necessary for treated ground water, collected LNAPL/DNAPL, or materials excavated during installation of designed remedial technologies.

Discharge to surface water. Collected ground water could be discharged to a surface water body after appropriate treatment and meeting SPDES permit limitations.

Discharge to ground water. Collected ground water could be re-injected to ground water through the use of vertical wells, horizontal wells, or a leach field.

Incineration. Combustion of LNAPL/DNAPL containing PCBs/VOCs in an off-site incineration unit may be applicable.

Disposal at a commercial TSCA or Subtitle D landfill. Disposal of materials excavated during installation of other technologies in a commercial TSCA or Subtitle D landfill may be appropriate.

Treatment actions
Treatment actions include thermal, chemical, and physical treatment technologies. Thermal treatment may be appropriate for materials excavated during installation of other technologies or for collected LNAPL/DNAPL. Potential thermal treatment process options include the following:

Incineration. Incineration is the combustion of PCBs/VOCs in soil, and may be appropriate materials excavated during installation of other technologies.

Low temperature thermal treatment. Low temperature thermal treatment involves the application of heat to thermally desorb PCBs/VOCs from soil, and may be appropriate for materials excavated during installation of other technologies.

Chemical treatment may be appropriate for water treatment, or for materials excavated during installation of other technologies. Potentially applicable chemical treatment process options include the following:

Chemical dechlorination. Chemical dechlorination is a nucleophillic substitution reaction using chemical reagents to dechlorinate PCBs in soil and may be appropriate for materials excavated during installation of other technologies.

Solvent extraction. Solvent extraction involves the use of a solvent to extract and concentrate PCBs from soil, and may be appropriate for materials excavated during installation of other technologies.

Oxidation. Oxidation is a water treatment technology that oxidizes PCBs/VOCs, creating non-toxic by products.

Physical treatment may be appropriate for treating ground water. Potentially applicable physical treatment process options include the following:

Air stripping. Air stripping is a physical treatment process in which air is used to remove VOCs from water.

Carbon adsorption. Activated carbon adsorbs PCBs/VOCs from water during contact. Upon saturation, spent carbon must be replaced or regenerated.

Phase separation. Phase separation is used to segregate LNAPL/DNAPL from water.

Soil washing. Soil washing is an aqueous based process where PCBs and finer-grained soil is separated from coarser-grained soil and may be appropriate for materials excavated during installation of other technologies.

Solidification/stabilization. This process involves the addition and mixing of solidification/stabilization agents to soil to immobilize PCBs, and may be appropriate for materials excavated during installation of other technologies.

GE's existing water treatment facility. The water treatment facility currently operated by GE at the site consists of air stripping, solids removal, and carbon adsorption. This facility has limited additional capacity that has been considered in the evaluation of technologies.

3.5. Evaluation of process options

The process options remaining after the initial screening were evaluated further according to the criteria of effectiveness, implementability, and cost. The effectiveness criterion includes the evaluation of:

- potential effectiveness of the process options in meeting remediation goals and handling the estimated volumes or areas of media
- potential effects on human health and the environment during construction and implementation
- experience and reliability of the process options

The technical and institutional aspects of implementing the process options were assessed for the implementability criterion. The capital and operation and maintenance (O&M) costs of each process option were evaluated as to whether they were high, medium, or low relative to the other process options of the same technology type.

Based on the evaluation, the more favorable process options were chosen as representative process options. Selecting representative process options simplifies the assembly of alternatives, but does not eliminate other process options. The process option actually used to implement remedial action may not be selected until the remedial design phase. A summary of the evaluation of process options and selected representative process options is presented as Table 3-2.

Representative process options selected for the site were: monitoring, municipal water supply, slurry wall, steel sheet piling with sealable joints, vertical extraction wells, horizontal extraction/injection wells, interceptor trenches, air stripping, carbon adsorption, and phase separation.

3.6. Remedial alternatives

General response actions, representative process options, and DNAPL collection methods evaluated in Appendix A were combined to form remedial alternatives. Six remedial alternatives have been developed (including the no further action alternative), and are described below.

3.6.1. Alternative 1 - No further action

This alternative would continue the ground water and DNAPL collection and treatment activities currently being conducted at the site. A monitoring program would be conducted, including measuring PCB and VOC concentrations in ground water, and downgradient monitoring wells would be observed for evidence of LNAPL/DNAPL migration on a routine basis. As part of the ongoing homeowner program, GE would also continue to encourage homeowners who are using ground water in the vicinity of the site to connect to the municipal water supply system.

3.6.2. Alternative 2 - hydraulic control

Alternative 2 would control migration of ground water and LNAPL/DNAPL through expansion of the existing ground water and DNAPL collection system. This expansion would result in collection of ground water from most of the existing recovery wells and would add ground water collection from the southeast corner of the facility, from areas west and south of the Foil Mill, and from the southwest corner of the facility, as described below. Additional collected ground water would be pumped to the existing water treatment facility (WTF). The total increase in flow to the existing WTF for this alternative is estimated to be approximately 61 gpm. For the purposes of this FS, it has been assumed that the existing WTF is capable of handling an additional flow of approximately 35 gpm. Therefore, the WTF would require upgrading to handle the additional flow proposed in this alternative. It is assumed that this upgrade would include installation of two additional 10,000 lb carbon adsorption units, required pumping and piping improvements, and a structure to house the above. This assumption is based on the sizing of the water pretreatment system installed at the GE Hudson Falls facility in September, 1993 (O'Brien & Gere, 1996c) which was designed to handle similar influent characteristics and flow rate.

Based on the hydraulic capacity of the existing air stripper, it is assumed that this air stripper would be capable of handling the additional flow in its current configuration. For the purposes of this FS, it has been assumed that it would not be necessary to add emission controls to the air stripper. If this alternative is implemented, potential air emissions would be evaluated during the design phase of the project. This evaluation would assess the impact of the additional PCB/VOC loading on the existing air stripper, identify whether design or operational modifications to the existing stripper would be required, and whether other options for air stripping are more cost-effective. Installation of an additional air stripper(s) near the collection point(s) may be appropriate.

The remedial alternatives, including Alternative 2, focus on collection and management of ground water and LNAPL/DNAPL in three areas at the facility. These areas include the southeast corner of the facility, the Foil Mill area, and the southwest corner of the facility. A conceptual configuration for Alternative 2 is presented in Figure 3-1.

Southeast corner of facility. The existing ground water collection system would continue to operate in this area at its present capacity. Additionally, approximately six wells would be installed along the southeast property boundary. These wells would be screened in a manner designed to minimize off-site migration within the transition zone. Ground water would be pumped from these wells to the existing air stripper and treatment facility. Estimated flow from these six wells is approximately 2 gpm/well (12 gpm total).

DNAPL collection would be performed using a horizontal well system, as recommended in Appendix A. The DNAPL collection system would utilize two horizontal extraction wells to collect DNAPL. The conceptual layout of the horizontal recovery wells is illustrated in Figure 3-1 and Figure A-5 (Appendix A). One horizontal well would be located along the downgradient edge of the recoverable DNAPL to intercept migrating DNAPL. The other horizontal well would be located parallel to the direction of DNAPL migration, along the approximate centerline of the plume. The horizontal wells would act as an underdrain system. An oil recovery system similar to the QED system currently in use in ORW-2 would be installed in each well. DNAPL piping would consist of double walled PVC piping equipped with a leak detection system. The electrical controls would also be routed underground through shallow trenches.

Foil Mill area. Ground water would be collected along the western and southern perimeter of the Foil Mill by installation of an interception trench. Conceptually, this trench would be approximately 850 ft long and an average of approximately 7 ft deep. The trench would be excavated down to the low permeability layer or within 2 to 3 ft of bedrock. A perforated pipe would be placed near the bottom of the trench and routed to a collection sump. The trench would be backfilled with permeable material, such as crushed stone. The sump would be equipped with a skimmer capable of removing LNAPL (kerosene) which may accumulate. Water from the sump would be pumped to the existing WTF. Estimated flow from the interception trench is 35 gpm, assuming a 2 ft drawdown in the trench.

Southwest corner of facility. The source of PCBs/VOCs to bedrock ground water in the southwest corner of the facility is not fully understood. Overburden ground water may be entering the bedrock along the route of the abandoned 30 inch sewer in this area. PCB/VOC concentrations in bedrock ground water may be reduced by collecting overburden ground water in the vicinity of this sewer. For the purposes of this FS, it has been assumed that this could be performed by using the sewer as a ground water collection system. Forrmer MH-27 would be converted to a sump, and ground water entering the sewer would be pumped to the existing water treatment facility. Collection of bedrock ground water from GM-11D would be discontinued on a trial basis and monitored to evaluate the effect of collection of overburden ground water on bedrock ground water quality at that location. A flow rate of 14 gpm has been estimated based on observations made by O'Brien & Gere personnel during dye testing activities (O'Brien & Gere, 1997).

3.6.3. Alternative 3 - hydraulic control with pretreatment

Alternative 3 would control migration of ground water and LNAPL/DNAPL through expansion of the existing ground water and DNAPL collection system in a manner similar to Alternative 2, with the exception of the method employed for management of ground water collected from the Foil Mill area interception trench. DNAPL collection would be performed through installation of the horizontal well collection system recommended in Appendix A. Ground water collected in the Foil Mill area would be directed to a pretreatment system to reduce VOC loading to the existing WTF, and therefore, the WTF would not be upgraded.

The pretreatment system would consist of a shallow tray air stripper. The air stripper effluent would be discharged to MH 4, and subsequently treated in the existing WTF. Although pretreatment would not reduce hydraulic loading, VOC loading to the WTF from the Foil Mill area would be reduced. Initially, water would be pumped from the interception trench at a rate that the existing WTF could accept (estimated to be 10 to 15 gpm after inclusion of water from the transition zone wells and from the sewer in the southwest corner of the facility). The existing WTF may be capable of handling higher hydraulic loading if VOC loading is reduced by the pretreatment system. Additionally, it may be possible to achieve hydraulic control in the vicinity of the Foil Mill at a flow rate which is lower than the 35 gpm estimated in Alternative 2. The actual flow rate that the WTF could accommodate and the flow rate required to achieve hydraulic control in the Foil Mill area would be identified by monitoring. Based on the results of this monitoring and performance of the WTF, additional actions could be performed, if required. These potential additional actions are described in Sections 3.6.3.1 and 3.6.3.2 below. A conceptual configuration for Alternative 3 is presented in Figure 3-2.

3.6.3.1. Alternative 3A - hydraulic control with re-injection

If monitoring and operational data indicated additional ground water collection was required to achieve hydraulic control in the Foil Mill area, the rate of ground water collection would be increased, and additional actions taken to manage this additional flow. Alternative 3A would include upgrading the pretreatment system installed as part of Alternative 3, and construction of a ground water re-injection system. Approximately 75% (25 gpm) of the water collected from the Foil Mill interception trench would be treated in the pretreatment system and re-injected through a horizontal well installed beneath the Foil Mill. The configuration of the pretreatment system would include a shallow tray air stripper and two 10,000 pound carbon adsorption units. This configuration is based on the water pretreatment system installed at the GE Hudson Falls facility in September, 1993 (O'Brien & Gere, 1996c), which was designed to handle similar influent characteristics and flow rate.

The remaining 25% of the flow originating from the interception trench would be pumped to the existing WTF. Total estimated increased flow from the southeast corner of the facility, the Foil Mill interception trench, and from the southwest corner of the facility to the existing WTF for this alternative is approximately 36 gpm. It is assumed that the WTF would be capable of treating this additional flow, and therefore would not require upgrading. A conceptual configuration for Alternative 3A is presented in Figure 3-3.

3.6.3.2. Alternative 3B - hydraulic control with upgradient barrier

Alternative 3B is an alternative to the approach presented in Alternative 3A for achieving hydraulic control in the Foil Mill area. Alternative 3B would include an upgradient barrier wall constructed along the north and east sides of the Foil Mill. A conceptual configuration for Alternative 3B is presented in Figure 3-4.

The purpose of this barrier wall would be to reduce flow into the interception trench constructed along the western and southern sides of the

Foil Mill. It is assumed that this barrier wall would be a conventional slurry wall approximately 550 ft long and an average of 16 ft deep. Installation of the upgradient barrier should reduce the flow of groundwater from the area northeast of the Foil Mill toward the collection trench. This reduction of flow will allow groundwater recovery rates to be reduced without reducing drawdown in the interception trench. After an initial draw down period, it is estimated that the flow from the interception trench would be approximately 5 gpm. This flow would be pretreated in the air stripper prior to discharge to MH4 and subsequent treatment in the WTF. The estimated 5 gpm from the interception trench, in addition to estimated flow from the transition zone wells and from the abandoned sewer in the southwest corner of the facility would result in an increase in flow to the existing WTF of approximately 31 gpm. It is assumed that the WTF could accommodate this flow without upgrading.

3.6.4. Alternative 4 - hydraulic control with downgradient barrier

Alternative 4 would consist of installation of a barrier wall and ground water collection wells along the southern and eastern property boundary. Alternative 4 would also include collection of ground water in an interception trench around the Foil Mill and from the abandoned sewer in the southwest corner of the facility in the same manner as described for Alternative 2. Water collected from these areas, and from the new wells installed adjacent to the barrier wall would be pumped to the existing WTF. Estimated additional hydraulic loading to the WTF for this alternative is approximately 49 gpm. It is assumed that the WTF would require upgrading in the same manner described for Alternative 2 to handle this additional flow. As described in Section 3.6.2, it has been assumed for the purposes of this FS that the air stripper would be capable of handling the additional loading in its current configuration. A conceptual configuration for Alternative 4 is presented in Figure 3-5.

Conceptually, the barrier wall would be constructed out of steel sheet piling. Steel sheet piling has been selected over a slurry wall due to the presence of TCE in the DNAPL, and the potential for the TCE to attack the slurry materials. The joints of the piling would be sealed with epoxy to minimize seepage past the barrier. The barrier would be approximately 850 ft long by 40 ft deep. This depth would be sufficient to key the sheet piling into the low permeability material, and is approximately 5 ft below the deepest area that DNAPL has been observed. This barrier would be supplemented with vertical recovery wells. Two wells would be located at the northeast corner of the barrier. One of these wells would be screened in the fine sand unit, and the other would be screened in the transition zone materials. An additional recovery well would be located at the southwest corner of the barrier, and would be screened in the fine sand unit.

Transition zone materials have not been identified in this area. The existing ground water collection system along the southern property boundary would be shut down upon installation of the barrier and associated new collection wells. It has been assumed that the flow from the two new shallow ground water wells would be approximately 25 gpm each, and 2 gpm from the transition zone well.

As the sheet piling wall would act as a barrier to DNAPL migration through the fine sand and transition zone materials, a horizontal well system for DNAPL collection would not be installed. Alternatively, the existing DNAPL collection system would be modified by redesign of ORW-2. The redesigning would include installation of a new larger diameter well adjacent to ORW-2. This well would be screened only in the area of DNAPL saturation, and would be equipped to minimize the amount of water in the well to reduce head on the DNAPL, potentially increasing recovery rates.

3.6.5. Alternative 5 - perimeter barrier with site dewatering

Alternative 5 consists of installation of a vertical barrier around the perimeter of the site, followed by hydraulic control within the barrier to reduce the ground water elevation down to near the top of the low permeability layer, essentially dewatering the site. A conceptual configuration for Alternative 5 is presented in Figure 3-6.

The vertical barrier would consist of steel sheet piling with sealed joints installed along portions of the southern and eastern property line, as described for Alternative 4. This barrier would be supplemented by installation of a slurry wall along the remainder of the perimeter of the site. This slurry wall would extend down to the top of rock or the low permeability layer, and would be approximately 3,650 ft long and an average of 25 feet deep. It is assumed that the existing ground water collection system in the southeast corner of the facility would be inoperative after the installation of the barrier wall; therefore, two new ground water recovery wells would be installed near the southeast corner of the facility, within the confines of the barrier wall and in the recoverable DNAPL plume. These new wells would be designed to collect a sufficient volume of water to reduce and maintain the ground water elevation within the perimeter barrier to near the top of the low permeability layer. These wells would also be designed to collect DNAPL. It is assumed that the existing WTF would be able to manage flow from these new recovery wells in its current configuration.

4. Identification of potentially applicable or relevant and appropriate requirements (ARARs)

This FS was conducted in accordance with USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988a), which requires that the remedial alternatives be evaluated for compliance with ARARs. Section 121(d) of CERCLA, as amended by SARA, requires that remedial actions comply with ARARs under federal or state environmental law at the completion of remedial action. Applicable requirements are defined in the *CERCLA Compliance with Other Laws Manual* (USEPA, 1988b) as those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or circumstance at a site. Accordingly, relevant and appropriate requirements are defined as those requirements that, while not specifically applicable to a given substance or circumstance, address concerns or situations sufficiently similar that their use is well suited to that site.

Three categories of ARARs are required to be considered: chemical-specific, location-specific, and action-specific.

- Chemical-specific ARARs are health-based or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values. These numerical values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment.

- Location-specific ARARs set restrictions on activities based on the characteristics of the site or its immediate environs.

- Action-specific ARARs set controls or restrictions on particular types of remedial actions once the remedial actions have been identified as part of a remedial alternative.

A remedial alternative that does not attain all ARARs may be selected under CERCLA, provided that one or more of six waiver conditions are met, and the alternative remains protective of human health and the environment. The six waiver conditions are:

- interim measures
- greater risk to health and the environment
- technical impracticability
- equivalent standard of performance
- inconsistent application of state requirements
- fund balancing.

Potential ARARs for the site are identified and described below. Evaluation of compliance with ARARs for each remedial alternative is documented in Section 5.

Remedial activities will be conducted in accordance with pertinent federal and state ARARs. It is anticipated that remediation will be performed pursuant to an Order on Consent with the State of New York; therefore, no state permits will be needed for activities performed as part of this remediation. Although state permits will not be required, the remedial activities will need to meet the substantive requirements of pertinent state regulations.

The New York State Class GA Ground Water Quality Standards in 6 KNOCKER Part 703 are applicable to ground water in New York State. As described in Section 3.1, these standards have been identified as potential chemical-specific ARARs for the site.

No location-specific ARARs have been identified for the site. The site is not located in or adjacent to a wetland, or a 100-year floodplain. Additionally, the site is not considered to have historical significance.

Regulations that have been identified as potential action-specific ARARs include:

Toxic Substances Control Act (TSCA) Regulations. Regulations promulgated under TSCA (40 CFR 761) specify treatment, storage, and disposal requirements for PCBs based on their form and concentration. These regulations are potentially applicable to the remedial alternatives involving handling and disposal of materials as they apply to materials containing PCBs at concentrations greater than 50 mg/kg upon excavation. While none of the remedial alternatives described in Section 3.6 includes soil excavation as a component, limited excavation may be required during construction of the interception trench or barrier walls. This excavated soil may contain PCBs at concentrations exceeding 50 mg/kg. Additionally, recovered DNAPL contains PCBs at concentrations exceeding 500 mg/l. The subparts of 40 CFR 761 that are potentially applicable include:

- 40 CFR 761.1 - Applicability
- 40 CFR 761.40 - Marking Requirements
- 40 CFR 761.45 - Marking Formats
- 40 CFR 761.60 - Disposal Requirements
- 40 CFR 761.65 - Storage for Disposal
- 40 CFR 761.75 - Chemical Waste Landfills
- 40 CFR 761.79 - Decontamination
- 40 CFR 761.180 - Records and Monitoring
- 40 CFR 761.207, 208, 209, 215 and 218 - Recordkeeping and Reporting
- TSCA's Compliance Program Policy No. 6-PCB-2.

Safe Drinking Water Act. The underground injection control program described in 40 CFR Parts 144 and 146 would be potentially applicable to re-injection of treated ground water.

New York State ground water quality standards. New York State ground water quality standards in 6 KNOCKER Part 703 include standards that regulate discharges to ground water and therefore is a potentially applicable action-specific ARAR as re-injection of treated ground water would require compliance with these standards.

New York State Hazardous Waste Regulations. PCBs at concentrations greater than 50 parts per million (ppm) are listed as a hazardous waste by New York State (NYS) hazardous waste regulations in 6 KNOCKER Part 371. Therefore, soil which is removed from the site as part of construction (and is subsequently generated as a waste) and which contains PCBs at concentrations greater than 50 ppm will be considered a hazardous waste in NYS. The following NYS hazardous waste regulations have been identified as potentially applicable to implementation of the alternatives:

- 6 KNOCKER Part 364 - Waste Transporter Permits
- 6 KNOCKER Part 372 - Hazardous Waste Manifest System and Related Standards for Generators, Transporters, and Facilities
- 6 KNOCKER Part 373 - Hazardous Waste Treatment, Storage, and Disposal Facility Requirements.
- 6 KNOCKER Part 376 - Land Disposal Restrictions

State Pollutant Discharge Elimination System (SPDES). On-site treatment with discharge to on-site ground water would not require a SPDES permit; however, compliance with the substantive SPDES requirements would be required. Alternatively, NYSDEC approval under the SPDES program (6 KNOCKER Part 750-757) would be required to modify the existing SPDES permit for the existing treatment facility to add water collected as a result of implementation of remedial alternatives.

Department of Transportation (DOT) Regulations. The following DOT regulations are potentially applicable to transportation of hazardous materials removed from the site:

- 49 CFR 172 Use of Hazardous Materials Tables and Communications
- 49 CFR 173 Requirements for Shipping and Packaging
- 49 CFR 174 Carriage by Rail
- 49 CFR 177 Carriage by Public Highway
- 49 CFR 178 Specifications for Packaging
- 49 CFR 179 Tank Car Specifications.

Occupational Safety and Health Administration (OSHA) Regulations. OSHA requirements for worker safety contained in 29 CFR 1910 and 29 CFR 1926 are potentially applicable for remediation activities. Construction tasks would be implemented in accordance with these requirements.

NYS Air Quality Standards and Emission Limits. 6 KNOCKER Parts 257 and 212 set forth the NYS air quality standards and air quality emission limits. As PCBs are not highly volatile, PCBs are not expected to be a source of air pollution will be created during the remedial activities. However, these standards are potentially applicable to operation of an air stripper to remove VOCs.

5. Detailed analysis of alternatives

5.1. Individual analysis of alternatives

In the individual analysis of alternatives, the remedial alternatives were evaluated with respect to the nine evaluation criteria. A summary of the individual analysis of alternatives is presented in Table 5-1.

5.1.1. Overall protection of human health and the environment

The analysis of each alternative with respect to overall protection of human health and the environment provides an evaluation of whether the alternative would achieve and maintain adequate protection and a description of how protection would be achieved through treatment, engineering, and for institutional controls. The individual analysis of each remedial alternative with respect to this criterion is presented in Table 5-1.

5.1.2. Compliance with applicable or relevant and appropriate requirements (ARARs)

Identification of ARARs was provided in Section 4 of this report. Evaluation of compliance with ARARs for each remedial alternative is summarized in Table 5-1.

5.1.3. Long-term effectiveness and permanence

For the evaluation of long-term effectiveness and permanence, the potential for future off-site migration of ground water containing PCBs/VOCs and LNAPL/DNAPL and the adequacy and reliability of the technologies utilized to control this migration were assessed for each alternative. The individual analysis of each remedial alternative with respect to this criterion is presented in Table 5-1.

5.1.4. Reduction of toxicity, mobility, or volume through treatment

The analysis of reduction of toxicity, mobility, or volume through treatment included an assessment of the treatment process used and materials treated; the amount of hazardous materials destroyed or treated; the degree of expected reductions in toxicity, mobility, and volume; the degree to which treatment is irreversible; and the type and quantity of residuals remaining after treatment. The individual analysis of each remedial alternative with respect to this criterion is presented in Table 5-1.

5.1.5. Short-term effectiveness

The short-term effectiveness criterion addressed the protection of workers and the community during construction and implementation of each alternative, environmental effects resulting from implementation of each alternative, and the time required to achieve remedial objectives. The individual analysis of each remedial alternative with respect to this criterion is presented in Table 5-1.

5.1.6. Implementability

The analysis of implementability involved the assessment of the following: the ability to construct and operate technologies, the reliability of technologies, the ease of undertaking additional remedial action, the ability to monitor the effectiveness of each remedy, the ability to obtain necessary approvals from other agencies, and the availability of services, capacities, equipment, materials and specialists. Results of evaluation of implementability for each alternative are presented in Table 5-1.

5.1.7. Cost

The objective of evaluating costs during the detailed analysis of alternatives was to make comparative analyses among alternatives based on cost. Cost estimates were prepared based on readily available vendor information and quotations, cost estimating guides and experience. Capital costs are those required to implement a remedy and include both direct and indirect capital costs. Annual operation and maintenance costs are costs which are expected to be incurred yearly throughout implementation of the remedy. The estimated capital and operation and maintenance costs were calculated for each alternative along with a present worth cost, which represents the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action. Present worth costs were calculated for the life of the alternative (up to 30 years) at a 5% discount rate.

Detailed cost estimates for Alternatives 1, 2, 3, 4, and 5 are presented in Tables 5-2 through 5-6, respectively. The cost estimate for Alternative 3

(Table 5-4) includes costs for implementation for Alternatives 3A and 3B as separate line items. A summary of estimated costs for each alternative is presented in Table 5-1. Cost estimates are considered preliminary, but are sufficiently detailed for purposes of comparing the alternatives in this FS. Costs associated with the selected remedial alternative will be refined during remedial design.

5.1.8. State acceptance

State acceptance of the alternatives is addressed by development of a preliminary remedial action plan (PRAP), and in the Record of Decision (ROD) following the public comment period.

5.1.9. Community acceptance

Community acceptance will be addressed in the ROD following the public comment period on the PRAP.

5.2. Comparative analysis of alternatives

5.2.1. Overall protection of human health and the environment

Evaluation of overall protection of human health and the environment has been based on the degree that the implementation of each alternative would address the site-related risks identified in the risk assessment (O'Brien & Gere, 1997).

The existing ground water recovery system has successfully reduced PCB/VOC concentrations in the southern plume and the associated springs. Alternatives 2 and 3 (upgraded as required, i.e., Alternative 3A or 3B) should reduce these concentrations at a faster rate than Alternative 1 by collecting transition zone ground water along the southern property line, reducing the influence transition zone ground water may be having on shallow ground water in the southern plume. This additional collection of ground water from the transition zone will reduce the potential for PCBs/VOCs to migrate off-site. Alternatives 4 and 5 should also reduce PCB/VOC concentrations in the southern plume by providing a barrier to shallow and transition zone ground water migration off-site. Alternatives 2, 3 (upgraded as required), 4, and 5 would be expected to be reduce

PCB/VOC concentrations in the southern plume within the same approximate time frame, as each alternative would begin to minimize migration of ground water containing PCBs/VOCs off-site when installation was completed.

5.2.2. Compliance with ARARs

Alternatives 1 through 5 would comply with the ARARs identified in Section 4, with the exception of NYSDEC AWQC. It is not anticipated that NYSDEC AWQC will be attained in on-site ground water for an extended period of time due to the presence of the LNAPL/DNAPL at the site. Alternatives 2 and 3 (upgraded as required) provide the most aggressive collection of LNAPL and DNAPL and would be expected to have the best potential for long-term reductions in PCB/VOC concentrations in ground water on-site. Alternative 4 provides LNAPL rates similar to Alternatives 2 and 3; however, DNAPL recovery rates would be lower. Alternative 5 does not include LNAPL recovery, and would provide DNAPL recovery at a lower rate than Alternatives 2 and 3.

Off-site compliance with NYSDEC AWQC would likely be achieved by Alternatives 2, 3 (upgraded as required), 4, and 5. The length of time until these criteria are met would be dependent upon the efficiency of the ground water and LNAPL/DNAPL control systems, and is considered to be similar for Alternatives 2, 3, 4, and 5.

5.2.3. Long term effectiveness and permanence

Long term effectiveness and permanence is a function of the efficiency of the ground water and LNAPL/DNAPL control systems, which is considered to approximately equal for Alternatives 2, 3 (upgraded as required), 4, and 5. However, adequate operation and maintenance of the ground water and LNAPL/DNAPL recovery systems is critical for satisfactory long term performance, particularly for Alternatives 2 and 3 (including Alternative 3A and 3B). Operation and maintenance activities, though still required, would not be as critical for Alternatives 4 or 5 due to the presence of physical containment in addition to hydraulic containment of ground water and LNAPL/DNAPL recovery.

5.2.4. Reduction of toxicity, mobility, or volume through treatment

Reduction of toxicity, mobility, or volume through treatment is proportional to the volume of ground water collected and treated on-site and the volume of LNAPL/DNAPL collected and treated off-site (incineration). Alternatives 2 and 3 include the collection of the largest volume of ground water and LNAPL/DNAPL. Alternatives that collect proportionally less ground water and/or LNAPL/DNAPL and therefore would have less impact per unit of time on removing PCBs/VOCs from ground water are (in descending order of expected mass of PCBs/VOCs removed per unit of time) Alternatives 4, 1, and 5.

5.2.5. Short term effectiveness

The containment provided by Alternatives 4 and 5 is expected to be effective upon installation; however, residual concentrations of PCBs/VOCs are likely to remain in downgradient off-site ground water for a period of time after installation. The degree of short term effectiveness achieved by implementation of the remaining alternatives is dependent upon the efficiency of the ground water and LNAPL/DNAPL collection systems. Short term effectiveness is considered to be approximately equal for Alternatives 2 and 3 (upgraded as required). This criterion does not apply to Alternative 1, as it has already been implemented.

5.2.6. Implementability

Alternative 1 has already been implemented. Alternatives 2 and 3 are expected to be readily implementable. The installation of horizontal wells would require accurate location control to place the wells at the desired elevation and to avoid underground utilities. Alternatives 4 and 5 are also considered to be readily implementable; however, installation of the barrier walls for these alternatives would likely result in short term interruptions in traffic patterns at the facility.

5.2.7. Cost

Conceptual cost estimates for each alternative are presented in Tables 5-2 through 5-6. Based on the estimated 30 year present worth presented in these tables, the least expensive alternative is Alternative 3 (with the exception of Alternative 1), and the most expensive is Alternative 5.

5.2.8. State acceptance

State acceptance will be addressed by development of a PRAP, and in the ROD following public comment on the PRAP.

5.2.9. Community acceptance

Community acceptance will be addressed in the ROD following public comment on the PRAP.

6. Summary and recommendations

The results of the site characterization activities, the risk assessment, and potential ARARs were evaluated to develop remedial action objectives for the site. These RAOs consist of :

- prevent, to the extent practicable, ingestion of ground water affected by the site that does not attain NYSDEC Class GA AWQC
- prevent, to the extent practicable, off-site migration of ground water that does not attain NYSDEC Class GA AWQC
- prevent, to the extent practicable, migration of LNAPL/DNAPL off the site

Other goals of the project, although not specifically RAOs, consist of:

- satisfy corrective action obligations pursuant to the facility's RCRA Part 373 permit for SWMUs, as described in the approved RI/FS work plan
- continue efforts to address ground water migration in the southern plume

To achieve these goals and objectives, general response actions, technologies, and process options were identified, screened, evaluated, and combined into potential remedial alternatives. These alternatives are:

- Alternative 1 - no further action
- Alternative 2 - hydraulic control
- Alternative 3 - hydraulic control with pretreatment
- Alternative 4 - hydraulic control with downgradient barrier
- Alternative 5 - perimeter barrier with site dewatering

In addition, Alternatives 3A (hydraulic control with reinjection) and 3B (hydraulic control with upgradient barrier) were developed to include enhancements to Alternative 3, which may be appropriate to implement based on operation and monitoring information.

The results of the detailed and comparative analysis of alternatives presented in Section 5 indicate that Alternatives 2, 3 (expanded as required), 4, and 5 are capable of achieving the RAOs.

Implementation of Alternative 3 is recommended as it represents the best balance of the evaluation criteria, and is cost-effective. Alternative 3 provides ground water recovery around the Foil Mill area through use of an interception trench, ground water recovery in the southwest corner of the site, ground water recovery in the southeast corner of the site, and an aggressive DNAPL recovery system. Implementation of this alternative provides flexibility in optimizing the use GE's existing WTF. Upgrading of this alternative by implementation of Alternatives 3A or 3B would be performed if actual monitoring and operational data indicated that it was required to enhance hydraulic control in the vicinity of the Foil Mill.

References

Dames & Moore. 1994. Outfall 004 Investigation Report. October 28, 1994.

Dunn Geoscience Corporation. 1990a. Hydrogeologic Evaluation of Recovery Well RW-1/1A, GE Company Fort Edward Facility, Fort Edward, New York.

Dunn Geoscience Corporation. 1990b. On-Site Remedial Plan. GE Company Fort Edward Facility, Fort Edward, New York.

Geraghty & Miller. January 1983. Hydrogeology of the General Electric Company Capacitor Plant, Fort Edward, NY.

Lawler, Matusky & Skelly Engineers. 1985. Revised Remedial Investigation Report, GE Capacitor Plant, Fort Edward, New York, December 1985.

Lawler, Matusky & Skelly Engineers. 1988. Feasibility Study Off-Site, Shallow Aquifer, GE Capacitor Plant, Fort Edward, New York, January 1988.

Lawler, Matusky & Skelly Engineers. 1989. Revised On-Site Feasibility Study, GE Capacitor Plant, Fort Edward, New York, May 1989.

O'Brien & Gere Engineers, Inc., 1997. Remedial Investigation Report. General Electric Company Fort Edward Facility. January 1997.

O'Brien & Gere Engineers, Inc., 1996a. Annual Ground Water Monitoring and Remedial Systems Operation Report. General Electric Company Fort Edward Facility.

O'Brien & Gere Engineers, Inc., 1996b. Outfall 004 IRM Summary Report. General Electric Company Fort Edward Facility. July, 1996.

O'Brien & Gere Engineers, Inc., 1996c. Summary Report. Hudson Falls Operable Unit 3 Interim Remedial Measures. July 1996.

O'Brien & Gere Engineers, Inc. 1995. Remedial Investigation/Feasibility Study Final Work Plan. April, 1995.

O'Brien & Gere Engineers, Inc. 1994a. DNAPL Recovery Well Evaluation. May, 1994.

O'Brien & Gere Engineers, Inc. 1994b. Foil Mill Trench and Tank Observations. March, 1994.

O'Brien & Gere Engineers, Inc. 1994c. AOC Assessment Report. May, 1994.

USEPA, 1988a. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Washington, D.C. October 1988.

USEPA, 1988b. CERCLA Compliance with Other Laws Manual. Washington, D.C. August 1988.

Table 3-1. Screening of Technologies and Process Options

General response action	Remedial technology	Process option	Description	Screening comments
No further action	None	Not applicable	No action (beyond activities currently being performed)	Required for consideration by NCP
Institutional actions	Access restrictions	Land use restrictions	Land use restrictions for area of contamination	Potentially applicable
		Fencing	Installation of fencing surrounding the site	Potentially applicable
		Sign posting	Installation of signs warning of presence of contaminated materials	Potentially applicable
	Monitoring	Ground and surface water monitoring	Periodic sampling and analysis to document ground and surface water quality	Potentially applicable
	Alternative water supply	Municipal water supply	Connect homeowners who use ground water to municipal supply	Applicable, already implemented (to extent homeowners choose to participate).
Containment actions	Flow diversion	Slurry wall	Constructed in a vertical trench under a slurry of clay-like material. Slurry is most commonly a mixture of bentonite and water. Excavation and disposal of soil would be required.	Potentially applicable

Table 3-1. Screening of Technologies and Process Options

General response action	Remedial technology	Process option	Description	Screening comments
Containment actions (cont'd)	Flow diversion (cont'd)	Vibrated beam wall	Constructed by vibrating beams into ground and injecting sealant down annulus of beams, creating a low permeability wall without excavation of soil.	Potentially applicable
		Jet grout wall	Constructed by high pressure injection of grout down bore holes spaced ⅓ to 1 ft apart, creating a wall of grout without excavation of soil.	Potentially applicable
		Auger mix wall	Constructed by using a soil mixing auger to mix soil with slurry *in situ*.	Potentially applicable
		HDPE sheet piling	Constructed by driving steel sheets into ground using vibration or excavation of a trench. Joints are sealable	Potentially applicable for upgradient barrier (PCBs/VOCs may attack HDPE)
		Steel sheet piling	Constructed by driving steel sheets into ground using electric hammer vibration or diesel hammers, without excavation of soil.	Potentially applicable

Table 3-1. Screening of Technologies and Process Options

General response action	Remedial technology	Process option	Description	Screening comments
Containment actions (cont'd)	Flow diversion (cont'd)	Steel sheet piling with sealable joints	Constructed by driving steel sheets into ground using electrical hammer vibration or direct hammers. Larger annulus joints are grouted with sealant, thereby reducing the permeability of the wall.	Potentially applicable
Collection actions	Extraction	Vertical extraction wells	Installation of vertical wells to pump and collect ground water and/or NAPL	Potentially applicable
		Horizontal extraction wells	Installation of horizontal wells to pump and collect ground water and/or NAPL	Potentially applicable
	Interception	Interceptor trenches	Installation of trench filled with highly permeable material, collection of ground water from within trench	Potentially applicable
Collection enhancement actions	Injection	Surfactant injection	Injection of surfactant to subsurface to increase NAPL mobility and recovery potential	Potentially applicable
		Hot air injection	Injection of hot air to subsurface to elevate temperature and vapor pressure to increase NAPL mobility and recovery potential	Potentially applicable

Table 3-1. Screening of Technologies and Process Options

General response action	Remedial technology	Process option	Description	Screening comments
Collection enhancement actions (cont'd)	Injection (cont'd)	Steam injection	Injection of hot air to subsurface to elevate temperature and vapor pressure to increase NAPL mobility and recovery potential	Potentially applicable
		Co-solvent injection	Injection of co-solvents into subsurface to increase NAPL mobility and recovery potential	Potentially applicable
Disposal actions	Surface water discharge	Discharge to Hudson River	Discharge of treated water through existing SPDES permitted outfall	Potentially applicable
	Ground water discharge	Vertical Wells	Re-injection of treated water to ground water through vertical wells	Potentially applicable
		Horizontal Wells	Re-injection of treated water to ground water through horizontal wells	Potentially applicable
		Leachfield	Re-injection of treated water to ground water through leachfield	Potentially applicable
	Incineration	Off-site incinerator	Combustion of NAPL containing PCBs/VOCs	Potentially applicable

Table 3-1. Screening of Technologies and Process Options

General response action	Remedial technology	Process option	Description	Screening comments
Disposal actions (cont'd)	Commercial landfill	TSCA landfill	Transportation and disposal of TSCA-regulated soil at a commercial permitted landfill	Potentially applicable for disposal of materials excavated during installation of other remedial technologies.
	Commercial landfill	Subtitle D landfill	Transportation and disposal of non-TSCA-regulated soil at a commercial permitted landfill	Potentially applicable for disposal of materials excavated during installation of other remedial technologies.
Treatment actions	Thermal treatment	Incineration	Combustion of PCBs/VOCs in soil in mobile on-site or off-site incineration unit	Potentially applicable for disposal of materials excavated during installation of other remedial technologies.
		Low temperature thermal treatment	Application of heat to desorb PCBs/VOCs from soil	Potentially applicable for disposal of materials excavated during installation of other remedial technologies.
	Chemical treatment	Chemical dechlorination	Nucleophilic substitution reaction using chemical reagents to dechlorinate PCBs in soil	Potentially applicable for disposal of materials excavated during installation of other remedial technologies.

Table 3-1. Screening of Technologies and Process Options

General response action	Remedial technology	Process option	Description	Screening comments
Treatment actions (cont'd)	Chemical treatment (cont'd)	Solvent extraction	Use of solvent to extract and concentrate PCBs from soil	Potentially applicable for disposal of materials excavated during installation of other remedial technologies.
		Oxidation	Use of ultraviolet light to oxidize PCBS/VOCs ("UV Chemox")	Potentially applicable
	Physical treatment	Air stripping	Volatilization of VOCs from water	Potentially applicable for removal of VOCs, not applicable for PCBs
		Carbon adsorption	Adsorbs PCBs/VOCs from water	Potentially applicable
		Phase separation	Separates NAPL from water	Potentially applicable
		Soil washing	Aqueous-based separation of PCBs and finer-grained soil from coarser grained soil	Potentially applicable for disposal of materials excavated during installation of other remedial technologies.
		Solidification/ stabilization	Addition and mixing of solidification/stabilization agents to soil to immobilize PCBs	Potentially applicable for disposal of materials excavated during installation of other remedial technologies.

Table 3-1. Screening of Technologies and Process Options

General response action	Remedial technology	Process option	Description	Screening comments
Treatment actions (cont'd)	Biological treatment	*In situ*	Degradation of PCBs in soil and ground water in place by enhancing conditions for naturally occurring microorganisms	Potentially applicable
	Existing treatment facility	(existing facility)	Air stripping, solids removal, carbon adsorption	Currently implemented

Table 3-2. Evaluation of technologies and process options

General Response Action	Remedial Technology	Process Option	Effectiveness	Implementability	Cost
No further action	None	Not applicable.	May not be effective method of controlling migration of ground water and/or NAPL off-site	Readily Implementable.	No capital costs. No additional O&M costs.
Institutional actions	Access restrictions	Land use restrictions	Effective for providing notice of land use restrictions. Effectiveness dependent on adherence to restrictions.	Implementable dependent on property owners cooperation	Low capital No O&M
		Fencing	Effectively minimizes access to contaminated area	Implementable, much of facility already fenced, fencing around springs readily implemented	Low capital Low O&M
		Sign posting	Effectively warns trespassers of presence of contamination	Implementable	Low capital Low O&M
	Monitoring	Ground and surface water monitoring*	Effective method for monitoring change in contaminant concentrations over time. Useful for evaluating remedy effectiveness.	Readily Implementable.	No additional capital costs. No additional O&M costs.
	Alternative water supply	Municipal water supply*	Effective to prevent ingestion of ground water affected by the site	Already implemented (where homeowners choose to participate)	Low capital No O&M
Containmen t actions	Flow diversion	Slurry wall*	Effective method of preventing migration of NAPL or ground water beyond wall. Effectiveness may be reduced over time if NAPL affects permeability of slurry.	Implementable.	Medium capital costs Low O&M costs.

* - Representative process option.
** - Representative process option evaluated in Appendix A.

Table 3-2. Evaluation of technologies and process options

General Response Action	Remedial Technology	Process Option	Effectiveness	Implementability	Cost
Containment actions (cont'd)	Flow diversion (cont'd)	Vibrated beam wall	Effectively prevents migration of NAPL or ground water beyond wall with no soil removed for surface disposal. However, slight deflection of beams potentially causes impermeability to be compromised. Site soils (sand) may increase potential for beam deflection.	Implementable.	Medium capital cost Low O&M costs.
		Jet grout wall	Effectively prevents migration of NAPL or ground water beyond wall with minimal soil removal for surface disposal. Effectiveness may be reduced over time if NAPL affects permeability of grout.	Implementable.	High capital cost Low O&M costs.
		Auger mix wall	Effectively prevents migration of NAPL or ground water beyond wall with minimal soil removed. Effectiveness may be reduced over time if NAPL affects permeability of slurry.	Implementable.	High capital costs Low O&M costs.
		HDPE sheet piling	Effectively prevents migration of ground water beyond sheet piles. May be degraded by VOCs in subsurface.	Implementable.	Medium capital costs. Medium O&M costs.
		Steel sheet piling	Effectively prevents migration of majority of NAPL and ground water beyond sheet piles with no earth material removed from the ground. However, potential exists for seepage of NAPL and ground water past the joints in the sheet piling.	Implementable.	Medium capital costs. Medium O&M costs.
		Steel sheet piling with sealable joints*	Effectively prevents migration of NAPL and ground water beyond sheet piles with no earth material removed from the ground and little or no potential for seepage between joints.	Implementable.	Medium capital costs. Low O&M costs.
Collection Actions	Extraction	Vertical extraction wells*	Effectively collects ground water for removal. Currently used at site with success.	Readily Implementable.	Medium capital costs. Medium O&M costs.
		Horizontal extraction wells*	Potentially effective means of collecting ground water or NAPL. Potentially more effective for DNAPL than vertical wells due to increased screen length exposed to DNAPL.	Implementable.	High capital cost Medium O&M costs.

* - Representative process option.
** - Representative process option evaluated in Appendix A.

Table 3-2. Evaluation of technologies and process options

General Response Action	Remedial Technology	Process Option	Effectiveness	Implementability	Cost
Collection Actions (cont'd)	Extraction (cont'd)	Interceptor trenches*	Effectively prevents migration of ground water or NAPL beyond trench and effectively collects fluid flowing into trench.	Readily Implementable.	Medium capital costs. Low O&M costs.
Collection Enhancement Actions	Injection	Surfactant injection	Potentially effective means to enhance NAPL recovery. Surfactant reduces interfacial tensions or increases contaminant solubility to improve NAPL extractability. Potential for uncontrolled migration of DNAPL and surfactant through unconsolidated/clay transition zone. Pilot study necessary.	Potentially Implementable.	Medium capital costs High O&M
		Hot air injection	Potentially effective means to enhance DNAPL recovery. Effectively reduces DNAPL viscosity and interfacial tension through increased temperature to improve extractability. Potential for uncontrolled mobilization of DNAPL through unconsolidated/clay transition zone. Pilot study is necessary.	Implementable.	Medium capital costs High O&M costs
		Steam injection**	Potentially effective means to enhance DNAPL recovery. Effectively reduces DNAPL viscosity and interfacial tension through increased temperature to improve extractability. Potential for uncontrolled mobilization of DNAPL through unconsolidated/clay transition zone.	Implementable. Excess steam available at plant.	Medium capital costs Medium O&M costs
		Co-solvent injection	Effectiveness not known. Technology in research stage and has not been proven for an application of this nature.	Implementable.	Medium capital costs High O&M costs
Disposal actions	Surface water discharge	Discharge to Hudson River*	Effective method to dispose of treated water.	Currently implemented.	Medium capital costs Medium O&M costs
	Ground water discharge	Vertical wells	Potentially effective method for disposal of treated water.	Implementable, installation in active building difficult	Medium capital costs Medium O&M costs

* - Representative process option.
** - Representative process option evaluated in Appendix A.

Table 3-2. Evaluation of technologies and process options

General Response Action	Remedial Technology	Process Option	Effectiveness	Implementability	Cost
Disposal actions (cont'd)	Ground water discharge (cont'd)	Horizontal wells*	Potentially effective method for disposal of treated water.	Implementable	High capital costs Medium O&M costs
		Leachfield	Potentially effective method for disposal of treated water.	Implementable	Medium capital costs Medium O&M costs
	Incineration	Off-site incinerator	Effective for disposal of NAPL.	Currently implemented	High capital costs Low O&M costs
	Commercial landfill	TSCA landfill*	Effective method for disposal of soil containing PCBs/VOCs.	Implementable	High capital costs Low O&M costs
		Subtitle D landfill	Effective method for disposal of soil containing PCBs/VOCs at low concentrations.	Implementable	Medium capital costs Low O&M costs
Treatment actions	Thermal treatment	Incineration	Effective PCB destruction technology; effective for meeting TSCA PCB destruction removal efficiency.	Implementable, soil volume requiring treatment likely insufficient to be cost effective	High capital costs Low O&M costs
		Low temperature thermal treatment	Effective for transfer of PCBs to vapor phase from soil for subsequent control; treatability testing necessary to evaluate effectiveness for achieving TSCA equivalent standard of performance to incineration.	Implementable, soil volume requiring treatment likely insufficient to be cost effective	High capital costs Low O&M costs
Treatment actions (cont'd)	Chemical treatment	Chemical dechlorination	Effective for PCB dechlorination and detoxification; treatability testing necessary to evaluate effectiveness for achieving TSCA equivalent standard of performance to incineration.	Implementable, soil volume requiring treatment likely insufficient to be cost effective	High capital costs Low O&M costs

* - Representative process option.
** - Representative process option evaluated in Appendix A.

Table 3-2. Evaluation of technologies and process options

General Response Action	Remedial Technology	Process Option	Effectiveness	Implementability	Cost
		Solvent extraction	Effective for transfer of PCBs to solvent stream requiring subsequent management; treatability testing necessary to evaluate effectiveness for achieving TSCA equivalent standard of performance to incineration.	Implementable, soil volume requiring treatment likely insufficient to be cost effective	High capital costs Low O&M costs
		Oxidation	Effective for removal of VOCs and PCBs from water	Implementable.	Medium capital costs. Low O&M costs.
	Physical treatment	Air stripping*	Effective for removal of VOCs from water. Not typically applicable for PCB removal.	Implementable.	Medium capital costs. Low O&M costs.
		Carbon adsorption*	Effective for removal of VOCs and PCBs from water	Implementable.	Medium capital costs. Low O&M costs.
		Phase separation*	Effective for separation of free NAPL from water	Implementable	Medium capital costs. Low O&M costs.
		Soil washing	Potentially effective for concentrating PCBs in finer soil fraction for subsequent management, if the majority of PCBs is associated with fines; treatability testing necessary to evaluate effectiveness for achieving TSCA equivalent standard of performance to incineration for coarser fraction.	Implementable, soil volume requiring treatment likely insufficient to be cost effective	High capital costs. Low O&M costs.
Treatment actions (cont'd)	Physical treatment (cont'd)	Solidification/ stabilization	Potentially effective for PCB immobilization; treatability testing necessary to evaluate leachate quality. Would not achieve TSCA equivalent standard of performance to incineration; long-term management controls required.	Implementable, soil volume requiring treatment likely insufficient to be cost effective	Medium capital costs. Medium O&M costs.
	Biological treatment	*In situ*	Effective for PCB dechlorination and degradation and degradation of VOCs in soil. Maintaining subsurface conditions amenable to biological treatment is difficult. Applicability to NAPL doubtful.	Potentially implementable.	Medium capital costs. Low O&M costs.

* - Representative process option.

** - Representative process option evaluated in Appendix A.

Table 3-2. Evaluation of technologies and process options

General Response Action	Remedial Technology	Process Option	Effectiveness	Implementability	Cost
Existing treatment facility	(existing facility)	Air stripping, solids removal, carbon adsorption	Effective for removal of PCBs/VOCs from water.	Currently implemented.	(NA)

* - Representative process option.
** - Representative process option evaluated in Appendix A.

Table 5-1. Detailed analysis of remedial alternatives

	Alternative 1 No further action	Alternative 2 Hydraulic control	Alternative 3, 3A, and 3B Hydraulic control with pretreatment	Alternative 4 Hydraulic control with downgradient barrier	Alternative 5 Perimeter barrier with site dewatering
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT					
Protection of Human Health	Continued operation of existing ground water recovery system along with institutional controls may continue to be protective of human health. Potential for future migration of PCBs/VOCs and NAPL may impact additional downgradient ground water users.	Expansion of ground water collection and treatment system will minimize potential for off-site migration of PCBs/VOCs in ground water. Use of horizontal wells for DNAPL collection will minimize potential for migration of DNAPL. These actions will reduce the potential for impact of PCBs/VOCs on downgradient ground water users. The use of appropriate protective equipment during remedial activities would minimize potential threat to remedial workers.	Expansion of ground water collection system and pretreatment will minimize potential for off-site migration of PCBs/VOCs in ground water. Use of horizontal wells for DNAPL collection will minimize potential for migration of DNAPL. These actions will reduce the potential for impact of PCBs/VOCs on downgradient ground water users. The use of appropriate protective equipment during remedial activities would minimize potential threat to remedial workers.	Expansion of ground water collection system and construction of a downgradient barrier will minimize potential for off-site migration of PCBs/VOCs in ground water. Downgradient barrier and use of vertical well for DNAPL collection will minimize potential for migration of DNAPL. These actions will reduce the potential for impact of PCBs/VOCs on downgradient ground water users. The use of appropriate protective equipment during remedial activities would minimize potential threat to remedial workers.	Installation of a perimeter barrier and site dewatering will minimize potential for off-site migration of PCBs/VOCs in ground water and DNAPL. Use of vertical wells for DNAPL collection will further reduce potential for migration of DNAPL. These actions will reduce the potential for impact of PCBs/VOCs on downgradient ground water users. The use of appropriate protective equipment during remedial activities would minimize potential threat to remedial workers.
Protection of Environment	Continued operation of existing ground water recovery system is expected to continue to reduce PCB/VOC concentrations in off-site springs, minimizing ecological exposure.	Additional ground water and DNAPL recovery is expected to continue to reduce PCB/VOC concentrations in off-site springs, minimizing ecological exposure.	Additional ground water and DNAPL recovery would reduce PCB/VOC concentrations in off-site springs, minimizing ecological exposure.	Additional ground water and DNAPL recovery/containment would reduce PCB/VOC concentrations in off-site springs, minimizing ecological exposure.	A perimeter barrier with site dewatering and DNAPL recovery with vertical wells would reduce PCB/VOC concentrations in off-site springs, minimizing ecological exposure.
COMPLIANCE WITH ARARs					
Chemical-Specific ARARs	Potential for future migration of ground water containing PCBs/VOCs or NAPL, increasing area in which NYSDEC AWQC are not attained.	Additional ground water and NAPL recovery should control future migration of ground water containing PCBs/VOCs or NAPL, decreasing area in which NYSDEC AWQC are not attained.	Additional ground water and NAPL recovery should control future migration of ground water containing PCBs/VOCs or NAPL, decreasing area in which NYSDEC AWQC are not attained.	Additional ground water and NAPL recovery/containment should control future migration of ground water containing PCBs/VOCs or NAPL, decreasing area in which NYSDEC AWQC are not attained.	Containment with limited ground water and NAPL recovery should control future migration of ground water containing PCBs/VOCs or NAPL, decreasing area in which NYSDEC AWQC are not attained.
Location-Specific ARARs	(none identified)	(none identified)	(none identified)	(none identified)	(none identified)

Table 5-1. Detailed analysis of remedial alternatives

	Alternative 1 No further action	Alternative 2 Hydraulic control	Alternative 3, 3A, and 3B Hydraulic control with pretreatment	Alternative 4 Hydraulic control with downgradient barrier	Alternative 5 Perimeter barrier with site dewatering
Action-Specific ARARs	New York State (NYSHWR) Hazardous Waste Regulations, TSCA, and DOT requirements for marking and transport of DNAPL, NYSHWR and TSCA generator requirements would continue to be attained.	Treatment and discharge of ground water from additional sources by WTF would require SPDES permit modification. NYSHWR, TSCA, and DOT requirements for marking, transport and disposal of DNAPL and soil excavated during installation of interception trench would be required. Compliance with NYSHWR and TSCA generator requirements would also be required.	Treatment and discharge of ground water from additional sources by WTF would require SPDES permit modification. Re-injection (Alternative 3A) of pretreated water would have to meet negotiated discharge limits and NYS ground water discharge standards and Safe Drinking Water Standards for reinjection of ground water, as they apply to reinjection of ground water to an area that is contained hydraulically. NYSHWR, TSCA, and DOT requirements for marking, transport and disposal of NAPL and soil excavated during installation of interception trench would be required. Compliance with NYSHWR and TSCA generator requirements would also be required. Operation of air stripper would require compliance with NYS Air Quality Standards and Emission Limits.	Treatment and discharge of ground water from additional sources by WTF would require SPDES permit modification. NYSHWR, TSCA, and DOT requirements for marking, transport and disposal of DNAPL and soil excavated during installation of interception trench would be required. Compliance with NYSHWR and TSCA generator requirements would also be required.	Treatment and discharge of ground water from additional sources by existing WTF would require SPDES permit modification. NYSHWR, TSCA, and DOT requirements for marking, transport and disposal of DNAPL and soil excavated during installation of perimeter barrier would be required. Compliance with NYSHWR and TSCA generator requirements would also be required.
LONG-TERM EFFECTIVENESS AND PERMANENCE					
Magnitude of Residual Risk	Potential for future off-site migration of ground water/NAPL containing PCBs/VOCs may impact additional downgradient ground water users. PCB/VOC concentrations in ground water and off-site springs should continue to decline.	Future off-site migration of ground water/NAPL containing PCBs/VOCs should be controlled. PCB/VOC concentrations in ground water and off-site springs should continue to decline.	Future off-site migration of ground water/NAPL containing PCBs/VOCs should be controlled. PCB/VOC concentrations in ground water and off-site springs should continue to decline.	Future off-site migration of ground water/NAPL containing PCBs/VOCs should be controlled. PCB/VOC concentrations in ground water and off-site springs should continue to decline.	Future off-site migration of ground water/NAPL containing PCBs/VOCs should be controlled. PCB/VOC concentrations in ground water and off-site springs should continue to decline.
Adequacy and Reliability of Controls	Ground water collection is an adequate and reliable measure for controlling ground water migration. Reliability and adequacy of DNAPL collection more difficult to predict due to tendency to migrate with gravity and grade of low permeability formations instead of hydraulic gradient. Current DNAPL collection system may not be adequate to control future off-site migration. Long-term operation and maintenance for ground water and DNAPL collection systems is required.	Ground water collection is an adequate and reliable measure for controlling ground water migration. Reliability and adequacy of DNAPL collection more difficult to predict due to tendency to migrate with gravity and grade of low permeability formations instead of hydraulic gradient. Horizontal well DNAPL collection system will likely be adequate to control future off-site migration. Long-term operation and maintenance for ground water and DNAPL collection systems is required.	Ground water collection is an adequate and reliable measure for controlling ground water migration. Reliability and adequacy of DNAPL collection more difficult to predict due to tendency to migrate with gravity and grade of low permeability formations instead of hydraulic gradient. Horizontal well DNAPL collection system will likely be adequate to control future off-site migration. Long-term operation and maintenance for ground water and DNAPL collection systems is required.	Ground water collection is an adequate and reliable measure for controlling ground water migration. Vertical barrier underlain by a low permeability formation is a reliable and adequate method of controlling DNAPL migration. Long-term operation and maintenance is required for ground water and DNAPL collection system, barrier requires minimal O & M.	Vertical barrier underlain by a low permeability formation is a reliable and adequate method of controlling ground water and DNAPL migration. Long-term operation and maintenance is required for ground water and DNAPL collection system, barrier requires minimal O & M.

Table 5-1. Detailed analysis of remedial alternatives

	Alternative 1 No further action	Alternative 2 Hydraulic control	Alternative 3, 3A, and 3B Hydraulic control with pretreatment	Alternative 4 Hydraulic control with downgradient barrier	Alternative 5 Perimeter barrier with site dewatering
			REDUCTION OF TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT		
Treatment Process Used and Materials Treated	PCBs/VOCs are removed from ground water by air stripping, solids removal, and carbon adsorption. DNAPL is disposed off-site by incineration.	PCBs/VOCs would be removed from ground water by air stripping, solids removal, and carbon adsorption. NAPL would be disposed off-site by incineration.	PCBs/VOCs would be removed from ground water by air stripping, solids removal, and carbon adsorption. NAPL would be disposed off-site by incineration.	PCBs/VOCs would be removed from ground water by air stripping, solids removal, and carbon adsorption. NAPL would be disposed off-site by incineration.	PCBs/VOCs would be removed from ground water by air stripping, solids removal, and carbon adsorption. NAPL would be disposed off-site by incineration.
Amount of Hazardous Materials Destroyed or Treated	Amount of PCBs/VOCs removed is proportional to their concentration in ground water, the rate and duration of ground water collection, and the rate and duration of DNAPL collection.	Amount of PCBs/VOCs removed would be proportional to their concentration in ground water, the rate and duration of ground water collection, and the rate and duration of NAPL collection.	Amount of PCBs/VOCs removed would be proportional to their concentration in ground water, the rate and duration of ground water collection, and the rate and duration of NAPL collection.	Amount of PCBs/VOCs removed would be proportional to their concentration in ground water, the rate and duration of ground water collection, and the rate and duration of NAPL collection.	Amount of PCBs/VOCs removed would be proportional to their concentration in ground water, the rate and duration of ground water collection, and the rate and duration of NAPL collection.
Degree of Expected Reductions in Toxicity, Mobility, and Volume	Reductions of PCB/VOC concentrations, mobility and volume will continue to occur. The magnitude of reduction is proportional to the rate and duration of ground water collection. Reduction of volume of DNAPL limited due to low recovery rate of existing system. LNAPL not currently collected.	Reductions of PCB/VOC concentrations, mobility and volume will occur. The magnitude of reduction is proportional to the rate and duration of ground water collection. Reduction of volume of NAPL expected with active NAPL recovery.	Reductions of PCB/VOC concentrations, mobility and volume will occur. The magnitude of reduction is proportional to the rate and duration of ground water collection. Reduction of volume of NAPL expected with active NAPL recovery.	Reductions of PCB/VOC concentrations, mobility and volume will occur. The magnitude of reduction is proportional to the rate and duration of ground water collection. Lower ground water recovery rates will result inless mass of PCBs/VOCs removed. Reduction of volume of NAPL limited due to expected low rate of NAPL recovery. Mobility minimized with downgradient barrier.	Reductions of PCB/VOC concentrations, mobility and volume expected to be limited by minimal volume of ground water collected. Reduction of volume of NAPL limited due to expected low rate of NAPL recovery. Mobility minimized with perimeter barrier and reduction of head on DNAPL.
Degree to Which Treatment is Irreversible	Treatment with carbon adsorption, air stripping, and solids removal is irreversible.	Treatment with carbon adsorption, air stripping, and solids removal is irreversible.	Pretreatment with air stripping, followed by treatment with carbon adsorption, and solids removal is irreversible.	Treatment with carbon adsorption, air stripping, and solids removal is irreversible.	Treatment with carbon adsorption, air stripping, and solids removal is irreversible.
Type and Quantity of Residuals Remaining After Treatment	Residual concentrations of PCBs/VOCs in treated ground water will be below SPDES permit limitations.	Residual concentrations of PCBs/VOCs in treated ground water will be below SPDES permit limitations.	Residual concentrations of PCBs/VOCs in treated ground water will be below SPDES permit limitations.	Residual concentrations of PCBs/VOCs in treated ground water will be below SPDES permit limitations.	Residual concentrations of PCBs/VOCs in treated ground water will be below SPDES permit limitations.
			SHORT-TERM EFFECTIVENESS		
Protection of Community During Remedial Actions	None required.	Minimal impact on community anticipated. Limited noise impacts associated with construction and drilling equipment.	Minimal impact on community anticipated. Limited noise impacts associated with construction and drilling equipment.	Moderate impact anticipated on residents living adjacent to facility due to noise by construction equipment and increase in truck traffic delivering materials to site.	Moderate impact anticipated on residents living adjacent to facility due to noise by construction equipment and increase in truck traffic delivering materials to site.
Protection of Workers During Remedial Actions	None required.	Appropriate protective equipment would be utilized during remedial activities.	Appropriate protective equipment would be utilized during remedial activities.	Appropriate protective equipment would be utilized during remedial activities.	Appropriate protective equipment would be utilized during remedial activities.
Environmental Impacts	None.	None anticipated.	None anticipated.	None anticipated.	None anticipated.

Table 5-1. Detailed analysis of remedial alternatives

	Alternative 1 No further action	Alternative 2 Hydraulic control	Alternative 3, 3A, and 3B Hydraulic control with pretreatment	Alternative 4 Hydraulic control with downgradient barrier	Alternative 5 Perimeter barrier with site dewatering
Time Until Remedial Action Objectives Are Achieved	RAOs may not be achieved.	Time required depends on efficiency of ground water and DNAPL collection system. Several years may be required for PCBs/VOCs in downgradient ground water to attenuate.	Time required depends on efficiency of ground water and DNAPL collection system. Several years may be required for PCBs/VOCs in downgradient ground water to attenuate.	Time required depends on efficiency of barrier wall and length of time required for PCBs/VOCs in downgradient ground water to attenuate. Several years may be required.	Time required depends on efficiency of barrier wall and length of time required for PCBs/VOCs in downgradient ground water to attenuate. Several years may be required.
			IMPLEMENTABILITY		
Ability to Construct and Operate the Technology	Not applicable.	Expansion of ground water collection system, including transition zone wells, interception trench, abandoned sewer and WTF upgrade readily constructed. Accuracy of horizontal well location critical to maximize DNAPL recovery and avoid underground utilities.	Expansion of ground water collection system, including transition zone wells, interception trench, abandoned sewer, and water pretreatment system readily constructed. Accuracy of horizontal well location critical to maximize DNAPL recovery and avoid underground utilities.	Installation of sheet piling barrier wall readily constructed. Temporary disruption of parking facilities required. Expansion of ground water collection system, including transition zone well, interception trench, abandoned sewer and shallow ground water collection wells at each end of barrier readily constructed.	Perimeter barrier is constructable. Off-site disposal of a significant portion of materials excavated from trench at RCRA permitted facility will likely be required. Temporary disruption of vehicle traffic at facility would be expected. New ground water/DNAPL recovery wells would be readily constructed.
Reliability of Technology	Ground water and DNAPL collection is reliable when adequate operation and maintenance is performed.	Ground water and DNAPL collection is reliable when adequate operation and maintenance is performed.	Ground water and DNAPL collection is reliable when adequate operation and maintenance is performed.	Downgradient barrier wall is reliable. Ground water and DNAPL collection is reliable when adequate operation and maintenance is performed..	Perimeter barrier is reliable. Ground water and DNAPL collection is reliable when adequate operation and maintenance is performed..
Ease of Undertaking Additional Remedial Actions, If Necessary	Minimal impact on ability to undertake future remedial actions.	Minimal impact on ability to undertake future remedial actions.	Minimal impact on ability to undertake future remedial actions.	Minimal impact on ability to undertake future remedial actions.	Minimal impact on ability to undertake future remedial actions.
Ability to Monitor Effectiveness of Remedy	Routine sampling and analysis of ground water, observations for NAPL would be adequate indicator of performance.	Routine sampling and analysis of ground water, observations for NAPL would be adequate indicator of performance.	Routine sampling and analysis of ground water, observations for NAPL would be adequate indicator of performance.	Routine sampling and analysis of ground water, observations for NAPL would be adequate indicator of performance.	Routine sampling and analysis of ground water, observations for NAPL would be adequate indicator of performance.
Coordination With Other Agencies	Continued cooperation with local municipal water supplier required.	NYSDEC approval of WTF SPDES permit modification required. Continued cooperation with local municipal water supplier required.	NYSDEC approval of WTF SPDES permit modification required. Continued cooperation with local municipal water supplier required.	NYSDEC approval of WTF SPDES permit modification required. Continued cooperation with local municipal water supplier required.	NYSDEC approval of WTF SPDES permit modification required. Continued cooperation with local municipal water supplier required.
Availability of Offsite Treatment, Storage and Disposal Services and Capacities	Continued availability of DNAPL disposal facility anticipated. Other off-site disposal not expected.	Continued availability of DNAPL disposal facility anticipated. Landfill and capacity for off-site disposal of materials removed from excavation for interceptor trench expected to be readily available.	Continued availability of DNAPL disposal facility anticipated. Landfill and capacity for off-site disposal of materials removed from excavation for interceptor trench expected to be readily available.	Continued availability of DNAPL disposal facility anticipated. Landfill and capacity for off-site disposal of materials removed from excavation for interceptor trench expected to be readily available.	Continued availability of DNAPL disposal facility anticipated. Landfill and capacity for off-site disposal of materials removed from excavation for barrier wall expected to be readily available.

Table 5-1. Detailed analysis of remedial alternatives

	Alternative 1 No further action	Alternative 2 Hydraulic control	Alternative 3, 3A, and 3B Hydraulic control with pretreatment	Alternative 4 Hydraulic control with downgradient barrier	Alternative 5 Perimeter barrier with site dewatering
Availability of Necessary Equipment, Specialists and Materials	Operation and maintenance personnel, sampling equipment and sampling personnel, and analytical laboratory readily available.	Drilling equipment and personnel, operation and maintenance personnel, sampling equipment and sampling personnel, and analytical laboratory readily available.	Drilling equipment and personnel, operation and maintenance personnel, sampling equipment and sampling personnel, and analytical laboratory readily available.	Drilling equipment and personnel, construction equipment and personnel, operation and maintenance personnel, sampling equipment and sampling personnel, and analytical laboratory readily available.	Drilling equipment and personnel, construction equipment and personnel, operation and maintenance personnel, sampling equipment and sampling personnel, and analytical laboratory readily available.
Availability of Prospective Technologies	None required.	Applied technologies readily available.	Applied technologies readily available.	Applied technologies readily available.	Applied technologies readily available.
COST					
Capital costs	(not applicable)	$1,201,688	$1,104,927 (Alt. 3) $1,499,517 (Alt. 3A) $1,487,727 (Alt. 3B)	$2,113,158	$5,112,572
LNAPL and DNAPL disposal present worth costs	(not applicable)	$1,104,217	$1,103,156 (Alt. 3) $1,103,156 (Alt. 3A) $1,103,156 (Alt. 3B)	$118,788	$118,788
Annual operation and maintenance costs	$55,000	$153,754	$92,819 (Alt. 3) $152,262 (Alt. 3A) $98,099 (Alt. 3B)	$169,483	$141,371
Operation and maintenance present worth costs (30 years)	$845,485	$2,363,572	$1,426,849 (Alt. 3) $2,340,628 (Alt. 3A) $1,508,016 (Alt. 3B)	$2,724,159	$2,173,226
Total Present Worth Costs (30 years)	$845,485	$4,669,477	$3,634,932 (Alt. 3) $4,943,301 (Alt. 3A) $4,098,899 (Alt. 3B)	$4,956,105	$7,404,585
STATE ACCEPTANCE					
To be documented in the Record of Decision (ROD).					
COMMUNITY ACCEPTANCE					
To be assessed following the public comment period and documented in the ROD.					

Table 5-2. Alternative 1 cost estimate.

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
ANNUAL OPERATING & MAINTENANCE COST (1)				
Quarterly monitoring program (2)	4	events	$10,000	$40,000
Annual Summary Report to NYSDEC	lump sum	lump sum		$15,000
ESTIMATED ANNUAL OPERATING & MAINTENANCE COST				$55,000
PRESENT WORTH OF ANNUAL OPERATING & MAINTENANCE COSTS FOR 30 YEARS (i=5%)				$845,485
TOTAL PRESENT WORTH COST ESTIMATE				**$845,485**

(1) - costs associated with operation of existing WTF or providing municipal water to homeowners not included as these activities will be conducted as part of each of the remedial alternatives.

(2) - assumes sampling 30 wells and analysis for PCBs/VOCs on a quarterly basis and observation of samples for presence of DNAPL.

Table 5-3. Alternative 2 cost estimate.

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
DIRECT CAPITAL COSTS				
Southeast corner of facilty (transistion zone recovery wells)				
Recovery wells (6 @ 40 feet deep)	240	VLF	$35.00	$8,400
Submersible water pump w/ controls	6	EA	$2,000.00	$12,000
2 in Double walled PVC pipe with leak detection system (1)	400	LF	$35.00	$14,000
Electrical service (1)	400	LF	$9.00	$3,600
Soil excavation for installation trenches (1)	120	CY	$20.00	$2,400
Disposal of soil containing PCBs/VOCs (2)	90	tons	$225.00	$20,250
Foil Mill area				
Excavation of ground water recovery trench (7 ft deep X 3 ft wide)	660	CY	$20.00	$13,200
Sheeting and bracing	lump sum	lump sum	$15,000.00	$15,000
Water management	lump sum	lump sum	$50,000.00	$50,000
Disposal of soil containing PCBs/VOCs (2)	495	tons	$225.00	$111,375
4 in perforated PVC collection pipe	850	LF	$5.00	$4,250
Backfill w/crushed stone	450	CY	$26.00	$11,700
8 ft dia. concrete sump (working depth 4 ft)	lump sum	lump sum	$8,000.00	$8,000
Product skimmer with holding tank	lump sum	lump sum	$8,200.00	$8,200
Sump pump with level control	lump sum	lump sum	$2,000.00	$2,000
2 in double-walled PVC pipe with leak detection system to MH 4	50	LF	$35.00	$1,750
Electrical service	100	LF	$9.00	$900
Soil excavation for installation trenches	30	CY	$20.00	$600
Disposal of soil containing PCBs/VOCs (2)	23	tons	$225.00	$5,063
Southwest corner of facility				
Installation of pump in MH 27 w/ level control	lump sum	lump sum	$2,000.00	$2,000
2 in double-walled PVC pipe with leak detection system	100	LF	$35.00	$3,500
Electrical service	100	LF	$9.00	$900
Soil excavation and backfill for installation trenches	30	CY	$20.00	$600
Disposal of soil containing PCBs/VOCs (2)	23	tons	$225.00	$5,063
Upgrade of water treatment facility (3)				
Carbon adsorption units (10,000 lb)	2	EA	$45,000.00	$90,000
Pumping modifications	lump sum	lump sum	$5,000.00	$5,000
WTF building expansion	300	SF	$70.00	$21,000
Piping	lump sum	lump sum	$5,000.00	$5,000
Electrical	lump sum	lump sum	$5,000.00	$5,000
Instrumentation and Controls	lump sum	lump sum	$5,000.00	$5,000
DNAPL collection (4)				
(horizontal wells)	lump sum	lump sum	$262,000.00	$262,000
OTHER COSTS				
Mobilization	lump sum	lump sum	$21,000	$21,000
Health & Safety	lump sum	lump sum	$25,000	$25,000
Air Monitoring	lump sum	lump sum	$15,000	$15,000
Site services	lump sum	lump sum	$50,000	$50,000
Site restoration	lump sum	lump sum	$20,000	$20,000
			Estimated Direct Capital Cost	$828,750

Table 5-3. Alternative 2 cost estimate.

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
INDIRECT CAPITAL COSTS				
Contingency Allowance (25%)				$207,188
Engineering Fees (15%)				$124,313
Legal Fees (5%)				$41,438
Estimated Indirect Capital Cost				$372,938
TOTAL ESTIMATED CAPITAL COST				$1,201,688
ANNUAL DNAPL DISPOSAL COST (4)				
(49 gpd x 365 days/ 55 gal/drum = 325 drums)				
55-gallon Collection Drums per Year	325	EA	$40.00	$13,000
Trasportation of Drums to TSCA Facility (1800 miles)	325	drums	$15.00	$4,875
Disposal of PCB-Contaminated DNAPL	325	drums	$550.00	$178,750
Estimated Annual DNAPL Disposal Cost				$196,625
PRESENT WORTH OF ANNUAL DNAPL DISPOSAL COST FOR 6.4 YEARS (i=5%)				$1,054,722
ANNUAL LNAPL DISPOSAL COST				
Annual LNAPL disposal cost (years 1 through 3)	10	drums	$605	$6,050
Annual LNAPL disposal cost (year 4)	9	drums	$605	$5,445
Annual LNAPL disposal cost (year 5)	8	drums	$605	$4,840
Annual LNAPL disposal cost (year 6)	7	drums	$605	$4,235
Annual LNAPL disposal cost (year 7)	6	drums	$605	$3,630
Annual LNAPL disposal cost (year 8)	5	drums	$605	$3,025
Annual LNAPL disposal cost (year 9)	4	drums	$605	$2,420
Annual LNAPL disposal cost (year 10)	3	drums	$605	$1,815
Annual LNAPL disposal cost (years 11 through 30)	3	drums	$605	$1,815
PRESENT WORTH OF ANNUAL LNAPL DISPOSAL COST (i=5%)				$49,495

Table 5-3. Alternative 2 cost estimate.

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
ANNUAL OPERATING & MAINTENANCE COST				
Quarterly monitoring program (5)	4	events	$10,000	$40,000
Annual Summary Report to NYSDEC	lump sum	lump sum	$15,000	$15,000
Pump maintenance and replacement	lump sum	lump sum	$5,000	$5,000
Operation of WTF (6)	lump sum	lump sum	$69,000	$69,000
LNAPL removal (2 hours/month)	24	HRS	$30	$720
Insurance (1% of Direct Capital Cost)				$12,017
Reserve Fund (1% Direct Capital Cost)				$12,017
ESTIMATED ANNUAL OPERATING & MAINTENANCE COST				$153,754
PRESENT WORTH OF ANNUAL OPERATING & MAINTENANCE COSTS FOR 30 YEARS (i=5%)				$2,363,572
TOTAL PRESENT WORTH COST ESTIMATE				$4,669,477

(1) - assumes tie in to existing ground water recovery system.

(2) - assumes 50% of soil removed from trench will require off-site disposal and treatment for VOCs would not be required prior to land disposal.

(3) - cost from "Evaluation and Upgrade Report, Fort Edward Wastewater Treatment Plant", O'Brien & Gere, September 1996.

(4) - cost from Table A-4 in Appendix A.

(5) - assumes ground water sampling and analysis in 20 wells, observation of samples for DNAPL migration.

(6) - estimated costs are for WTF expansion and do not include costs for operation of existing WTF. Labor cost for operation of WTF expansion not included as GE has indicated that existing staff would be sufficient.

Table 5-4. Alternative 3 cost estimate.

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
DIRECT CAPITAL COSTS				
Southeast corner of facilty (transistion zone recovery wells)				
Recovery wells (6 @ 40 feet deep)	240	VLF	$35.00	$8,400
Submersible water pump w/ controls	6	EA	$2,000.00	$12,000
2 in Double walled PVC pipe with leak detection system (1)	400	LF	$35.00	$14,000
Electrical service (1)	400	LF	$9.00	$3,600
Soil excavation for installation trenches (1)	120	CY	$20.00	$2,400
Disposal of soil containing PCBs/VOCs (2)	90	tons	$225.00	$20,250
Foil Mill area				
Excavation of ground water recovery trench (7 ft deep X 3 ft wide)	660	CY	$20.00	$13,200
Sheeting and bracing	lump sum	lump sum	$15,000.00	$15,000
Water management	lump sum	lump sum	$50,000.00	$50,000
Disposal of soil containing PCBs/VOCs (2)	495	tons	$225.00	$111,375
4 in perforated PVC collection pipe	850	LF	$5.00	$4,250
Backfill recovery trench w/crushed stone	450	CY	$26.00	$11,700
8 ft dia. concrete sump (working depth 4 ft)	lump sum	lump sum	$8,000.00	$8,000
Product skimmer with holding tank	lump sum	lump sum	$8,200.00	$8,200
Sump pump with level control	2	EA	$2,000.00	$4,000
2 in double-walled PVC pipe with leak detection system to MH4	50	LF	$35.00	$1,750
Shallow tray air stripper	1	EA	$44,000.00	$44,000
Electrical service	lump sum	lump sum	$5,000.00	$5,000
Soil excavation for installation trenches	15	CY	$20.00	$300
Disposal of soil containing PCBs/VOCs (2)	11	tons	$225.00	$2,531
Instrumentation and Controls	lump sum	lump sum	$5,000.00	$5,000
Structural modifications to Bldg. 40	lump sum	lump sum	$10,000.00	$10,000
Southwest corner of facility				
Installation of pump in MH 27 w/ level control	lump sum	lump sum	$2,000.00	$2,000
2 in double-walled PVC pipe with leak detection system	100	LF	$35.00	$3,500
Electrical service	100	LF	$9.00	$900
Soil excavation for installation trenches	30	CY	$20.00	$600
Disposal of soil containing PCBs/VOCs (2)	23	tons	$225.00	$5,063
DNAPL collection (3)				
(horizontal wells)	lump sum	lump sum	$262,000.00	$262,000
OTHER COSTS				
Mobilization	lump sum	lump sum	$23,000	$23,000
Health & Safety	lump sum	lump sum	$25,000	$25,000
Air Monitoring	lump sum	lump sum	$15,000	$15,000
Site services	lump sum	lump sum	$50,000	$50,000
Site restoration	lump sum	lump sum	$20,000	$20,000
		Estimated Direct Capital Cost		$762,019

Table 5-4. Alternative 3 cost estimate.

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
INDIRECT CAPITAL COSTS				
Contingency Allowance (25%)				$190,505
Engineering Fees (15%)				$114,303
Legal Fees (5%)				$38,101
Estimated Indirect Capital Cost				$342,908
TOTAL ESTIMATED CAPITAL COST				$1,104,927
ANNUAL DNAPL DISPOSAL COST (3)				
(49 gpd x 365 days/ 55 gal/drum = 325 drums)				
55-gallon Collection Drums per Year	325	EA	$40.00	$13,000
Trasportation of Drums to TSCA Facility (1800 miles)	325	Drums	$15.00	$4,875
Disposal of PCB-Contaminated DNAPL	325	Drums	$550.00	$178,750
Estimated Annual DNAPL Disposal Cost				$196,625
PRESENT WORTH OF ANNUAL DNAPL DISPOSAL COST FOR 6.4 YEARS (i=5%)				$1,054,722
ANNUAL LNAPL DISPOSAL COST				
Annual LNAPL disposal cost (years 1 through 3)	10	drums	$605	$6,050
Annual LNAPL disposal cost (year 4)	9	drums	$605	$5,445
Annual LNAPL disposal cost (year 5)	8	drums	$605	$4,840
Annual LNAPL disposal cost (year 6)	7	drums	$605	$4,235
Annual LNAPL disposal cost (year 7)	6	drums	$605	$3,630
Annual LNAPL disposal cost (year 8)	5	drums	$605	$3,025
Annual LNAPL disposal cost (year 9)	4	drums	$605	$2,420
Annual LNAPL disposal cost (year 10)	3	drums	$605	$1,815
Annual LNAPL disposal cost (years 11 through 30)	3	drums	$605	$1,815
PRESENT WORTH OF ANNUAL LNAPL DISPOSAL COST (i=5%)				$48,434
ANNUAL OPERATING & MAINTENANCE COST				
Quarterly monitoring program (4)	4	events	$10,000	$40,000
Annual Summary Report to NYSDEC	lump sum	lump sum	$15,000	$15,000
NAPL removal (2 hours/month)	24	HRS	$30	$720
Pump maintenance and replacement	lump sum	lump sum	$5,000	$5,000
Operation of water pretreatment facility (5)	lump sum	lump sum	$10,000	$10,000
Insurance (1% of Direct Capital Cost)				$11,049
Reserve Fund (1% Direct Capital Cost)				$11,049
ESTIMATED ANNUAL OPERATING & MAINTENANCE COST				$92,819
PRESENT WORTH OF ANNUAL OPERATING & MAINTENANCE COSTS FOR 30 YEARS (i=5%)				$1,426,849
TOTAL PRESENT WORTH COST ESTIMATE				$3,634,932

Table 5-4. Alternative 3 cost estimate.

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
ADDITIONAL COSTS FOR ALTERNATIVE 3A				
DIRECT CAPITAL COSTS				
Carbon adsorption units (10,000 lb)	2	EA	$45,000.00	$90,000
2 in. PVC pipe from treatment system to re-injection well	350	LF	$14.00	$4,900
6 in. horizontal re-injection well	400	LF	$200.00	$80,000
Disposal of PCB-Contaminated Drill Cuttings	30	TONS	$225.00	$6,750
Soil excavation for installation trenches	135	CY	$20.00	$2,700
Disposal of soil containing PCBs/VOCs (2)	101	tons	$225.00	$22,781
OTHER COSTS				
Mobilization	lump sum	lump sum	$15,000	$15,000
Health & Safety	lump sum	lump sum	$10,000	$10,000
Air Monitoring	lump sum	lump sum	$10,000	$10,000
Site services	lump sum	lump sum	$20,000	$20,000
Site restoration	lump sum	lump sum	$10,000	$10,000
Estimated Direct Capital Cost				$272,131
INDIRECT CAPITAL COSTS				
Contingency Allowance (25%)				$68,033
Engineering Fees (15%)				$40,820
Legal Fees (5%)				$13,607
Estimated Indirect Capital Cost				$122,459
TOTAL ESTIMATED CAPITAL COST				$394,590
ADDITIONAL ANNUAL OPERATING & MAINTENANCE COST				
Operation of water pretreatment facility (5)	lump sum	lump sum	$54,000	$54,000
Insurance (1% of Direct Capital Cost)				$2,721
Reserve Fund (1% Direct Capital Cost)				$2,721
ESTIMATED ANNUAL OPERATING & MAINTENANCE COST				$59,443
PRESENT WORTH OF ADDITIONAL ANNUAL OPERATING & MAINTENANCE COSTS FOR 30 YEARS (i=5%)				$913,779
TOTAL PRESENT WORTH COST ESTIMATE				$1,308,369

Table 5-4. Alternative 3 cost estimate.

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
ADDITIONAL COSTS FOR ALTERNATIVE 3B				
DIRECT CAPITAL COSTS				
Upgradient slurry wall (850 ft long X 16 ft deep X 3 ft wide)	13600	VSF	$15.00	$204,000
OTHER COSTS				
Mobilization	lump sum	lump sum	$10,000	$10,000
Health & Safety	lump sum	lump sum	$10,000	$10,000
Air Monitoring	lump sum	lump sum	$10,000	$10,000
Site services	lump sum	lump sum	$20,000	$20,000
Site restoration	lump sum	lump sum	$10,000	$10,000
Estimated Direct Capital Cost				$264,000
INDIRECT CAPITAL COSTS				
Contingency Allowance (25%)				$66,000
Engineering Fees (15%)				$39,600
Legal Fees (5%)				$13,200
Estimated Indirect Capital Cost				$118,800
TOTAL ESTIMATED CAPITAL COST				$382,800
ADDITIONAL ANNUAL OPERATING & MAINTENANCE COST				
Insurance (1% of Direct Capital Cost)				$2,640
Reserve Fund (1% Direct Capital Cost)				$2,640
ESTIMATED ADDITIONAL ANNUAL OPERATING & MAINTENANCE COST				$5,280
PRESENT WORTH OF ADDITIONAL ANNUAL OPERATING & MAINTENANCE COSTS FOR 30 YEARS (i=5%)				$81,167
TOTAL PRESENT WORTH COST ESTIMATE				$463,967

(1) - assumes tie in to existing ground water recovery system.

(2) - assumes 50% of soil removed from trench will require off-site disposal and treatment for VOCs would not be required prior to land disposal.

(3) - cost from Table A-4 in Appendix A.

(4) - assumes ground water sampling and analysis in 20 wells, observation of samples for DNAPL migration.

(5) - estimated costs are for pretreatment system and do not include costs for operation of existing WTF. Labor cost for operation of pretreatment syste not included as GE has indicated that existing staff would be sufficient.

Table 5-5. Alternative 4 cost estimate.

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
DIRECT CAPITAL COSTS				
Southeast corner of facilty				
Steel Sheet Piling with Sealed Joints (850 ft long X 40 ft deep)	34000	VSF	$26.00	$884,000
Recovery wells (2 @ 30 ft deep, 1 @ 40 ft deep)	100	VLF	$35.00	$3,500
Submersible water pump w/ controls	3	EA	$2,000.00	$6,000
2 in Double walled PVC pipe with leak detection system (1)	400	LF	$35.00	$14,000
Electrical service (1)	400	LF	$9.00	$3,600
Soil excavation for installation trenches (1)	120	CY	$20.00	$2,400
Disposal of soil containing PCBs/VOCs (2)	90	tons	$225.00	$20,250
Foil Mill area				
Excavation of ground water recovery trench (7 ft deep X 3 ft wide)	660	CY	$20.00	$13,200
Sheeting and bracing	lump sum	lump sum	$15,000.00	$15,000
Water management	lump sum	lump sum	$50,000.00	$50,000
Disposal of soil containing PCBs/VOCs (2)	495	tons	$225.00	$111,375
4 in perforated PVC collection pipe	850	LF	$5.00	$4,250
Backfill w/crushed stone	450	CY	$26.00	$11,700
8 ft dia. concrete sump (working depth 4 ft)	lump sum	lump sum	$8,000.00	$8,000
Product skimmer with holding tank	lump sum	lump sum	$8,200.00	$8,200
Sump pump with level control	lump sum	lump sum	$2,000.00	$2,000
2 in double-walled PVC pipe with leak detection system to MH4	50	LF	$35.00	$1,750
Electrical service	100	LF	$9.00	$900
Soil excavation for installation trenches	30	CY	$20.00	$600
Disposal of soil containing PCBs/VOCs (2)	23	tons	$225.00	$5,063
Southwest corner of facility				
Installation of pump in MH 27 w/ level control	lump sum	lump sum	$2,000.00	$2,000
2 in double-walled PVC pipe with leak detection system	100	LF	$35.00	$3,500
Electrical service	100	LF	$9.00	$900
Soil excavation for installation trenches	30	CY	$20.00	$600
Disposal of soil containing PCBs/VOCs (2)	23	tons	$225.00	$5,063
Upgrade of water treatment facility (3)				
Carbon adsorption units (10,000 lb)	2	EA	$45,000.00	$90,000
Pumping modifications	lump sum	lump sum	$5,000.00	$5,000
WTF building expansion	300	SF	$70.00	$21,000
Piping	lump sum	lump sum	$5,000.00	$5,000
Electrical	lump sum	lump sum	$5,000.00	$5,000
Instrumentation and Controls	lump sum	lump sum	$5,000.00	$5,000
DNAPL collection				
New vertical well at ORW-2	30	VLF	$50.00	$1,500
OTHER COSTS				
Mobilization	lump sum	lump sum	$37,000	$37,000
Health & Safety	lump sum	lump sum	$25,000	$25,000
Air Monitoring	lump sum	lump sum	$15,000	$15,000
Site services	lump sum	lump sum	$50,000	$50,000
Site restoration	lump sum	lump sum	$20,000	$20,000
			Estimated Direct Capital Cost	$1,457,350

Table 5-5. Alternative 4 cost estimate.

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
INDIRECT CAPITAL COSTS				
Contingency Allowance (25%)				$364,338
Engineering Fees (15%)				$218,603
Legal Fees (5%)				$72,868
			Estimated Indirect Capital Cost	$655,808
			TOTAL ESTIMATED CAPITAL COST	**$2,113,158**
ANNUAL LNAPL AND DNAPL DISPOSAL COST				
Annual disposal cost (years 1 through 3)	25	drums	$605	$15,125
Annual disposal cost (year 4)	21	drums	$605	$12,705
Annual disposal cost (year 5)	18	drums	$605	$10,890
Annual disposal cost (year 6)	15	drums	$605	$9,075
Annual disposal cost (year 7)	13	drums	$605	$7,865
Annual disposal cost (year 8)	11	drums	$605	$6,655
Annual disposal cost (year 9)	9	drums	$605	$5,445
Annual disposal cost (year 10)	8	drums	$605	$4,840
Annual disposal cost (years 11 through 30)	8	drums	$605	$4,840
			PRESENT WORTH OF ANNUAL LNAPL DISPOSAL COST (i=5%)	$118,788
Quarterly monitoring program (4)	4	events	$10,000	$40,000
Annual Summary Report to NYSDEC	lump sum	lump sum	$15,000	$15,000
NAPL removal (2 hrs/month)	24	HRS	$30	$720
Pump maintenance and replacement	lump sum	lump sum	$2,500	$2,500
Operation of WTF (5)	lump sum	lump sum	$69,000	$69,000
Insurance (1% of Direct Capital Cost)				$21,132
Reserve Fund (1% Direct Capital Cost)				$21,132
			ESTIMATED ANNUAL OPERATING & MAINTENANCE COST	$169,483
			PRESENT WORTH OF ANNUAL OPERATING & MAINTENANCE COSTS FOR 30 YEARS (i=5%)	$2,724,159
			TOTAL PRESENT WORTH COST ESTIMATE	**$4,956,105**

(1) - assumes tie in to existing ground water recovery system.

(2) - assumes 50% of soil removed from trench will require off-site disposal and treatment for VOCs would not be required prior to land disposal.

(3) - cost from "Evaluation and Upgrade Report, Fort Edward Wastewater Treatment Plant", O'Brien & Gere, September 1996.

(4) - assumes ground water sampling and analysis in 20 wells, observation of samples for DNAPL migration.

(5) - estimated costs are for WTF expansion and do not include costs for operation of existing WTF. Labor cost for operation of WTF expansion not included as GE has indicated that existing staff would be sufficient.

Table 5-6. Alternative 5 cost estimate.

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
DIRECT CAPITAL COSTS				
Southeast corner of facilty				
Water/DNAPL recovery wells (2 @ 35 ft deep)	70	VLF	$35.00	$2,450
2 in Double walled PVC pipe with leak detection system	900	LF	$35.00	$31,500
Electrical service (1)	50	LF	$9.00	$450
Submersible Water Pump with Level Control	2	EA	$2,000.00	$4,000
QED Pulse Pump including System Controls	2	EA	$3,378.00	$6,756
1" PVC Riser (Oil)	70	LF	$10.05	$704
2" PVC Riser (Water)	70	LF	$14.05	$984
Soil excavation for installation trenches (1)	280	CY	$20.00	$5,600
Disposal of soil containing PCBs/VOCs (2)	210	tons	$225.00	$47,250
Perimeter barrier				
Steel Sheet Piling with Sealed Joints (850 ft long X 40 ft deep)	34,000	VSF	$26.00	$884,000
Slurry wall (3,650 ft long X 25 ft deep X 3 ft wide)	91,250	VSF	$15.00	$1,368,750
Water Management	lump sum	lump sum	$50,000	$50,000
Disposal of soil containing PCBs/VOCs (2)	3,802	tons	$225.00	$855,469
Disposal of slurryl containing PCBs/VOCs	200	tons	$225.00	$45,000
OTHER COSTS				
Mobilization	lump sum	lump sum	$73,000	$73,000
Health & Safety	lump sum	lump sum	$25,000	$25,000
Air Monitoring	lump sum	lump sum	$25,000	$25,000
Site services	lump sum	lump sum	$50,000	$50,000
Site restoration	lump sum	lump sum	$50,000	$50,000
			Estimated Direct Capital Cost	$3,525,912
INDIRECT CAPITAL COSTS				
Contingency Allowance (25%)				$881,478
Engineering Fees (15%)				$528,887
Legal Fees (5%)				$176,296
			Estimated Indirect Capital Cost	$1,586,660
			TOTAL ESTIMATED CAPITAL COST	$5,112,572

Table 5-6. Alternative 5 cost estimate.

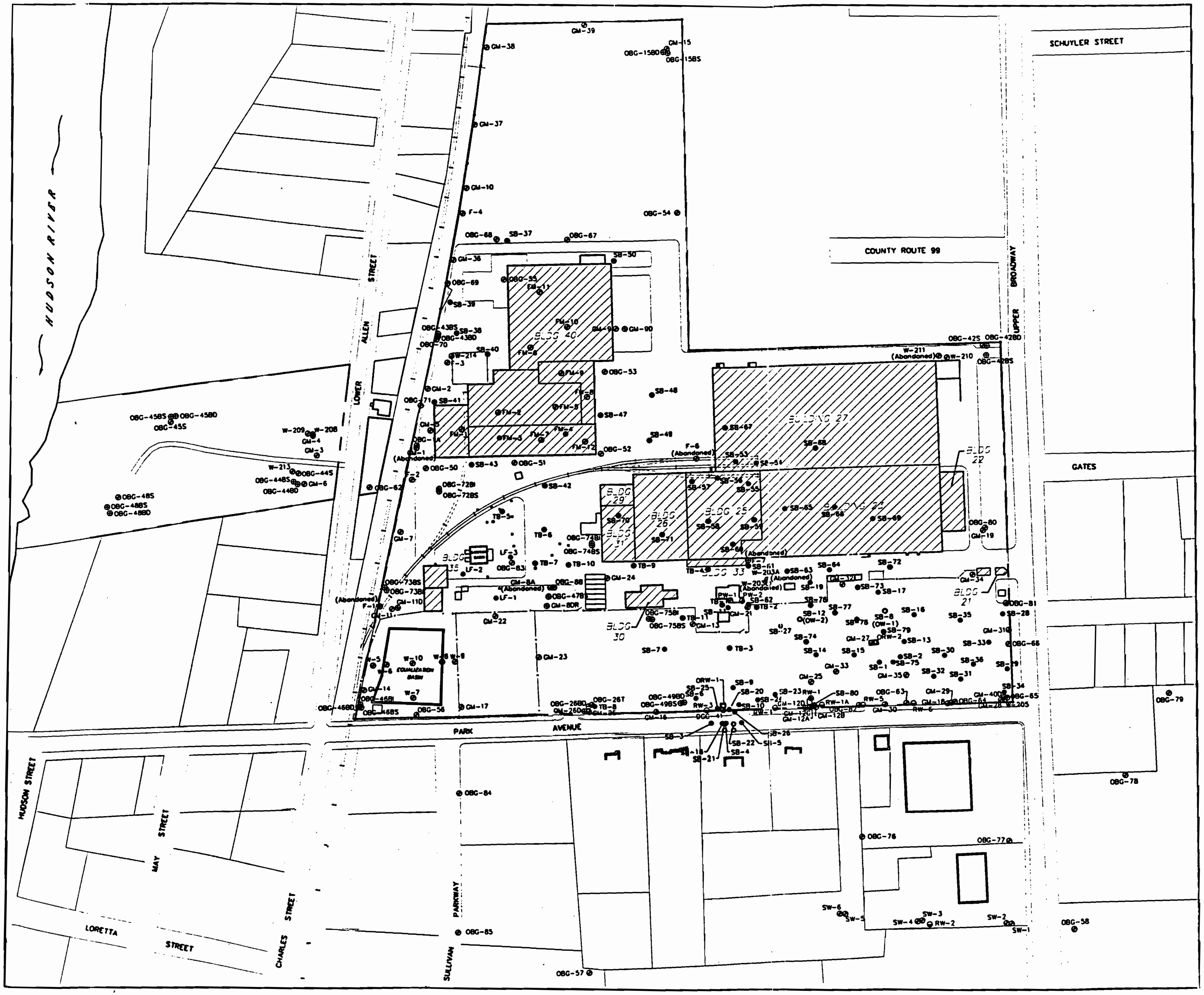
ITEM	QTY	UNITS	UNIT COST	TOTAL COST
ANNUAL LNAPL AND DNAPL DISPOSAL COST				
Annual disposal cost (years 1 through 3)	25	drums	$605	$15,125
Annual disposal cost (year 4)	21	drums	$605	$12,705
Annual disposal cost (year 5)	18	drums	$605	$10,890
Annual disposal cost (year 6)	15	drums	$605	$9,075
Annual disposal cost (year 7)	13	drums	$605	$7,865
Annual disposal cost (year 8)	11	drums	$605	$6,655
Annual disposal cost (year 9)	9	drums	$605	$5,445
Annual disposal cost (year 10)	8	drums	$605	$4,840
Annual disposal cost (years 11 through 30)	8	drums	$605	$4,840
PRESENT WORTH OF ANNUAL LNAPL DISPOSAL COST (i=5%)				$118,788
ANNUAL OPERATING & MAINTENANCE COST				
Quarterly monitoring program (3)	4	events	$5,000	$20,000
Annual Summary Report to NYSDEC	lump sum	lump sum	$15,000	$15,000
NAPL removal (2 hours/month)	104	HRS	$30	$3,120
Pump maintenance and replacement	lump sum	lump sum	$1,000	$1,000
Insurance (1% of Direct Capital Cost)				$51,126
Reserve Fund (1% Direct Capital Cost)				$51,126
ESTIMATED ANNUAL OPERATING & MAINTENANCE COST				$141,371
PRESENT WORTH OF ANNUAL OPERATING & MAINTENANCE COSTS FOR 30 YEARS (i=5%)				$2,173,226
TOTAL PRESENT WORTH COST ESTIMATE				**$7,404,585**

(1) - assumes tie in to existing ground water recovery system.

(2) - assumes 25% of soil removed from trench will require off-site disposal and treatment for VOCs would not be required prior to land disposal.

(3) - assumes ground water sampling and analysis in 15 wells, observation of samples for DNAPL migration.

FIGURE 2-1



LEGEND

- OBG-54 — LOCATION OF SHALLOW UNCONSOLIDATED UNIT MONITORING WELL
- OBG-42BS — LOCATION OF BEDROCK MONITORING WELL
- SB-43 — LOCATION OF SOIL BORING
- ORW-2 — LOCATION OF OIL RECOVERY WELL
- RW-5 — LOCATION SHALLOW UNCONSOLIDATED UNIT GROUND WATER RECOVERY WELL

GENERAL ELECTRIC COMPANY
FORT EDWARD, NEW YORK
REMEDIAL INVESTIGATION

SITE MAP

200 0 200
SCALE IN FEET

FILE NO. 5731.046-01F

O'BRIEN & GERE ENGINEERS, INC.

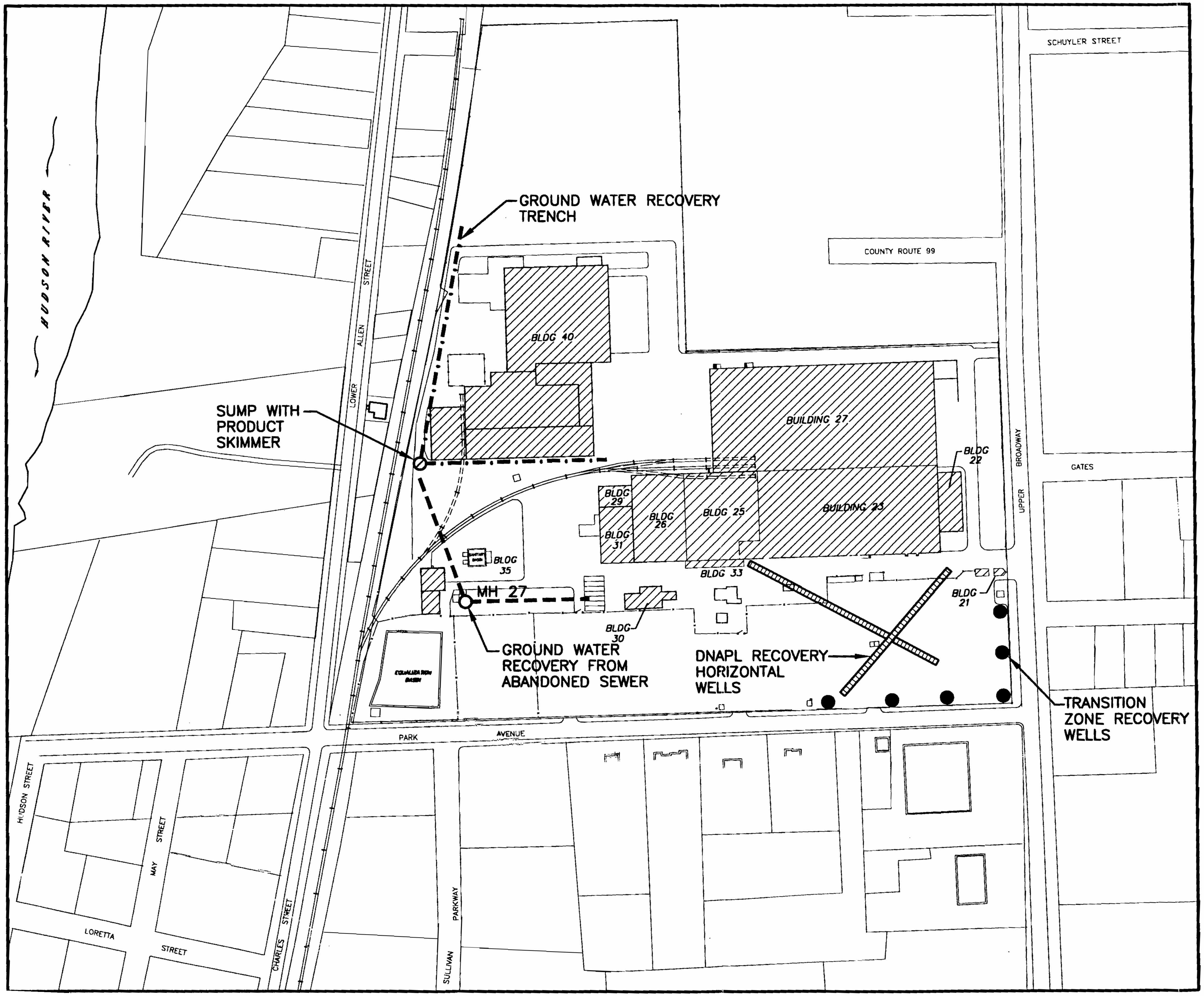
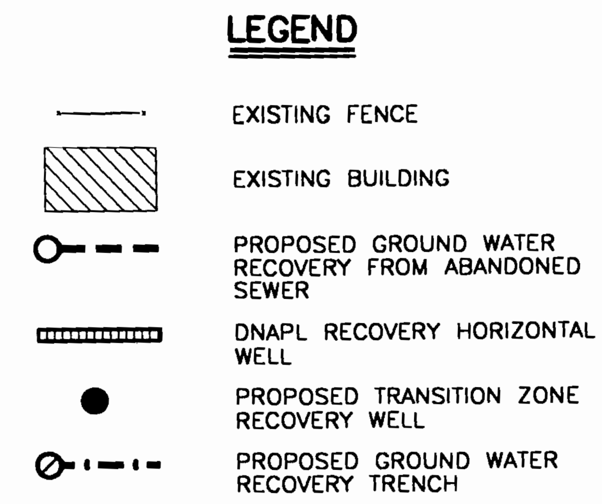


FIGURE 3-1



GENERAL ELECTRIC COMPANY
FORT EDWARD, NEW YORK
FEASIBILITY STUDY

ALTERNATIVE 2 PLAN

200 0 200

SCALE IN FEET

FILE NO. 5731.039

O'BRIEN & GERE ENGINEERS, INC.

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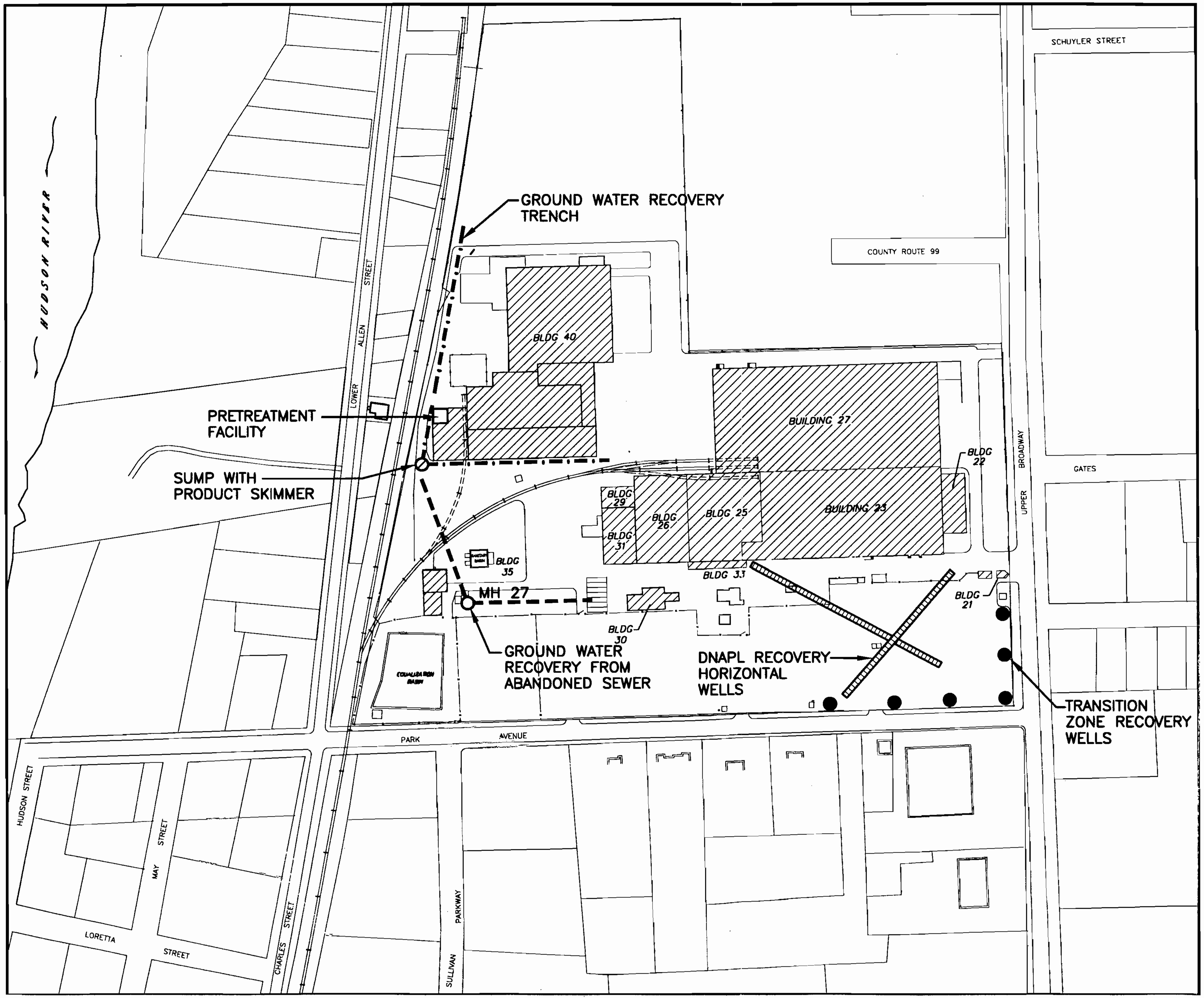
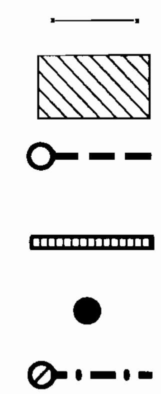


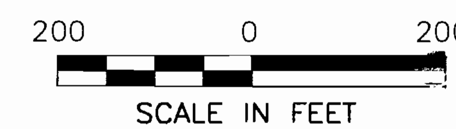
FIGURE 3-2

LEGEND



GENERAL ELECTRIC COMPANY
FORT EDWARD, NEW YORK
FEASIBILITY STUDY

ALTERNATIVE 3 PLAN



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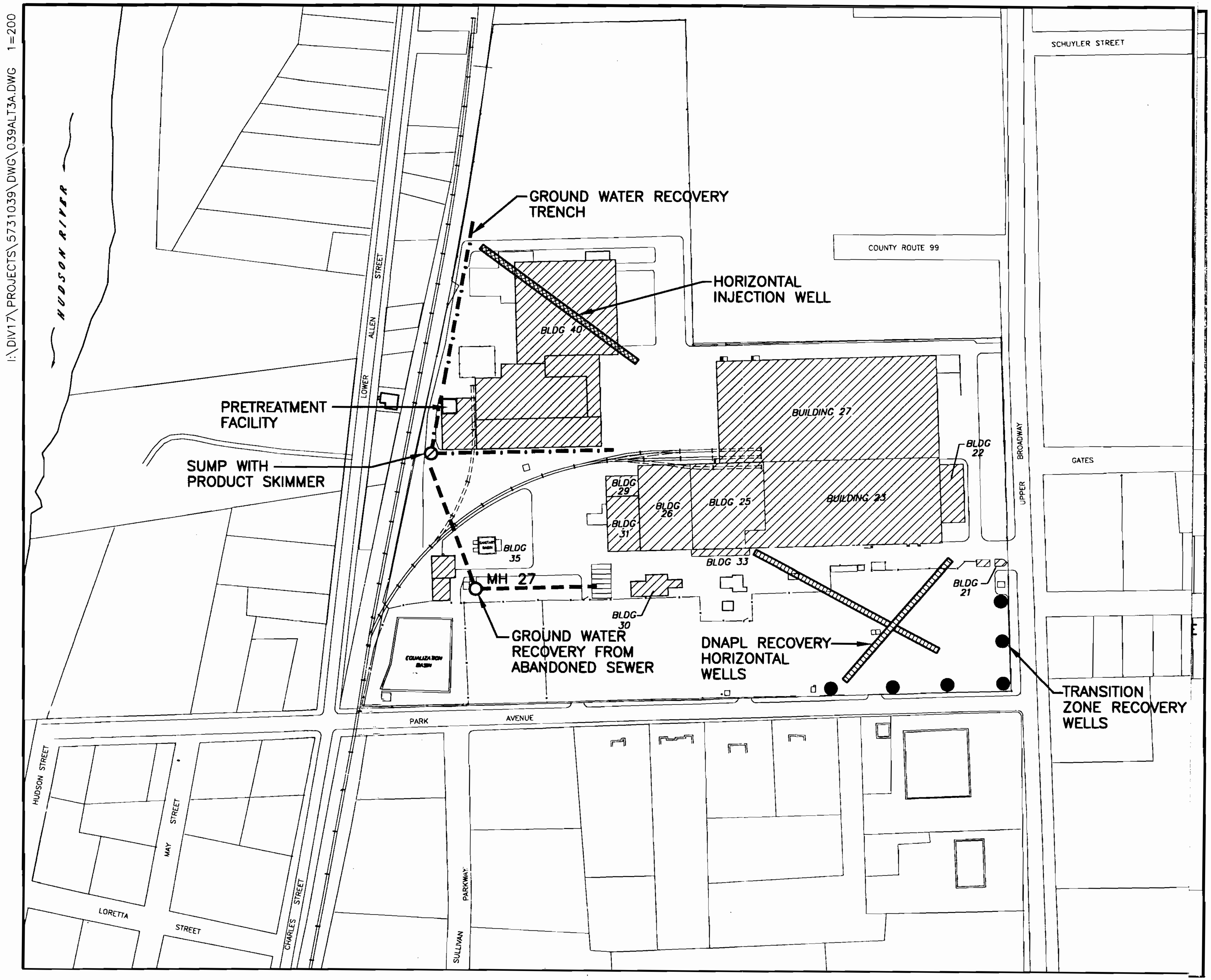


FIGURE 3-5

LEGEND

- EXISTING FENCE
- EXISTING BUILDING
- PROPOSED GROUND WATER RECOVERY FROM ABANDONED SEWER
- PROPOSED GROUND WATER RECOVERY TRENCH
- PROPOSED RECOVERY WELL
- SHEET PILING BARRIER

GENERAL ELECTRIC COMPANY
FORT EDWARD, NEW YORK
FEASIBILITY STUDY

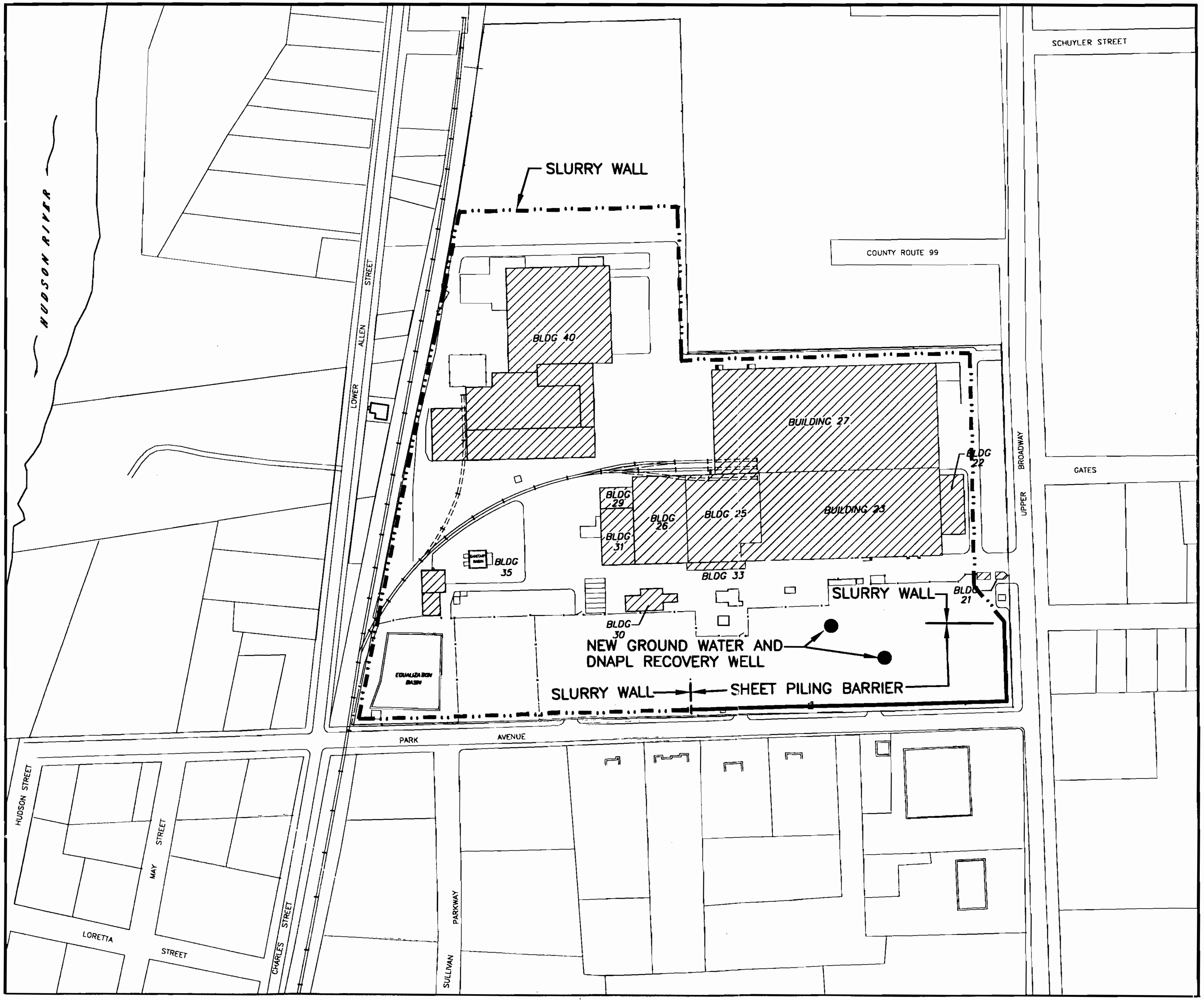
ALTERNATIVE 4 PLAN

200 0 200
SCALE IN FEET

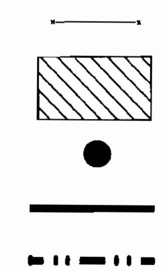
FILE NO. 5731.039

O'BRIEN & GERE ENGINEERS, INC.

FIGURE 3-6



LEGEND



- EXISTING FENCE
- EXISTING BUILDING
- PROPOSED RECOVERY WELL
- SHEET PILING BARRIER
- SLURRY WALL

GENERAL ELECTRIC COMPANY
FORT EDWARD, NEW YORK
FEASIBILITY STUDY

ALTERNATIVE 5 PLAN

200 0 200
SCALE IN FEET

FILE NO. 5731.039

O'BRIEN & GERE ENGINEERS, INC.

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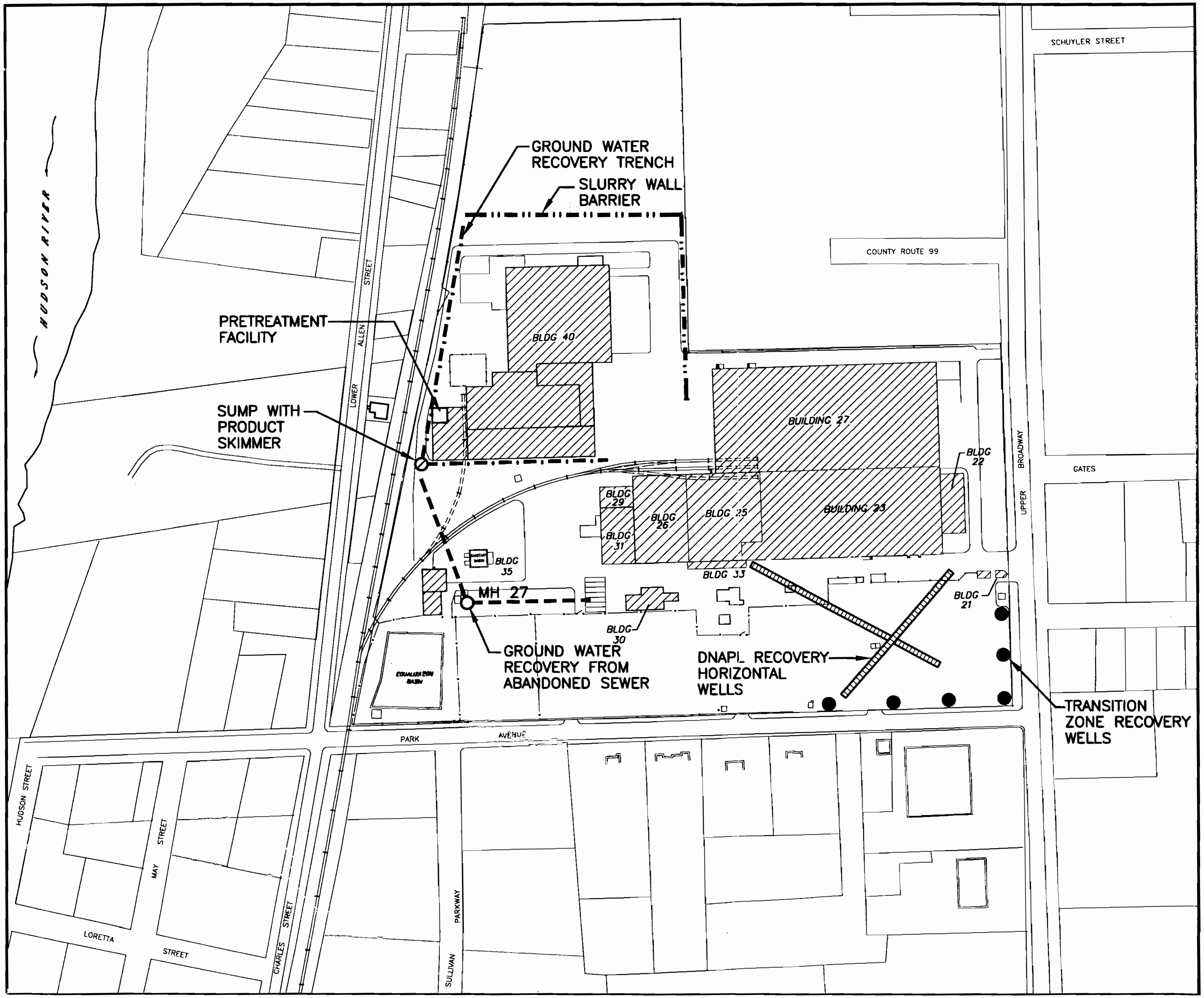
FIGURE 3–4



LEGEND

- EXISTING FENCE
- EXISTING BUILDING
- PROPOSED GROUND WATER RECOVERY FROM ABANDONED SEWER
- DNAPL RECOVERY HORIZONTAL WELL
- PROPOSED TRANSITION ZONE RECOVERY WELL
- PROPOSED GROUND WATER RECOVERY TRENCH
- PROPOSED SLURRY WALL BARRIER

GENERAL ELECTRIC COMPANY
FORT EDWARD, NEW YORK
FEASIBILITY STUDY

ALTERNATIVE 3B PLAN

200 0 200
SCALE IN FEET

FILE NO. 5731.039

O'BRIEN & GERE ENGINEERS, INC.

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Appendix A

DNAPL collection evaluation

O'BRIEN & GERE
ENGINEERS, INC.

APPENDIX A
DNAPL COLLECTION EVALUATION

Introduction
Prior to formulating the site wide remedial alternatives, an evaluation of methods to increase the rate of DNAPL recovery was performed. This evaluation was performed as it was considered likely that enhanced DNAPL collection would be a significant component of one or more of these alternatives. The results of the evaluation presented in this appendix have been incorporated into the DNAPL recovery component of the site-wide remedial alteratives.

Summary of DNAPL evaluation and collection activities
Significant efforts have been completed relative to assessing the extent of subsurface DNAPL in the southern portion of the plant (O'Brien & Gere, 1997). Subsurface PCB oil at the facility was initially discovered during the installation of monitoring well GM-27 in November 1983. A pumping system was installed and used to recover DNAPL from well GM-27 for 6 years starting in 1984. Approximately 1,329 gallons of DNAPL were pumped from GM-27. PCB oil was also discovered in a shallow ground water monitoring well, designated DGC-41, installed in April 1990.

In 1990 and 1995, two extensive DNAPL boring programs were conducted. In 1990, a total of twenty-four soil borings were completed to define the top of clay surface and evaluate the extent of DNAPL. To better define the horizontal and vertical distribution of DNAPL at the facility, an additional thirty-four boring were completed in 1995. Borings installed to identify DNAPL were drilled to the top of the low permeability clay or till layer. The results of these investigations indicate that the distribution of recoverable DNAPL in the subsurface is limited to the area beneath the south parking lot and a small area near the south property line defined by wells DGC-41 and ORW-2.

To address the identified extent of subsurface DNAPL, two recovery wells were installed. In April 1991, a DNAPL recovery system was installed in oil recovery well ORW-1, approximately 8 feet north of monitoring well DGC-41. Operation of ORW-1 began in April 1991. In July 1993, the original Techtron product pump was replaced with a QED Pulse Pump system comprised of a pneumatic bladder pump and pump control unit with self-contained compressor. Since initiation of recovery well ORW-1, approximately 77 gallons of DNAPL have been recovered from recovery well ORW-1. Based on observations from the 1990 and 1995 boring programs, it is believed that the areal extent of DNAPL is limited and recoverable DNAPL remains in the subsurface near recovery well ORW-1.

In May 1992, a DNAPL recovery system similar to the one operating in ORW-1 was installed in oil recovery well ORW-2, approximately 5 feet east of monitoring well GM-27. Installation and start up of a product recovery system at ORW-2 was deferred until an evaluation of the product recovery system at oil recovery well ORW-1 was complete. Since initiation of oil recovery activities at ORW-2 in October 1992, approximately 520 gallons of DNAPL have been recovered from ORW-2. Based on observations from the 1990 and 1995 boring programs, it is believed that a significant volume of recoverable DNAPL remains in the subsurface near oil recovery well ORW-2. The performance of the DNAPL recovery wells has been evaluated by O'Brien & Gere (O'Brien & Gere, 1994). Samples of DNAPL were submitted for PCB, volatile organic compounds (VOCs), and physical characteristics analyses. The results of these analyses are presented in Attachment A.

The likely source of the DNAPL at the site was the rail car off-loading area and bulk storage tank farm area located adjacent to the CCO Treat Area in Building 23. The DNAPL has generally migrated south/southeast. Currently, the approximate dimensions of the recoverable (pooled) area of the DNAPL plume are 110 by 230 feet. Although the surface of the low permeability layer varies in elevation (O'Brien & Gere, 1997), boring log data indicates that the approximate thickness of DNAPL is 2.5 ft. Assuming a porosity of 30% (O'Brien & Gere, 1994), the approximate volume of DNAPL within the void space of the soil within this area is 142,000 gallons. Assuming that the estimated DNAPL retention capacity of the site soil (the amount of DNAPL that will remain adsorbed to the aquifer material as unrecoverable residual DNAPL) is 20% (Cohen and Mercer 1993), the estimated recoverable volume of DNAPL is approximately 114,000 gallons.

Evaluation of technologies and process options for DNAPL recovery

General response actions which may be combined into alternatives to address the recoverable DNAPL plume include: institutional actions, containment actions, collection actions and collection enhancement actions. Although typically included in Feasibility Studies, the treatment general response action (including both *in situ* and *ex situ* treatment technologies) was not included in this evaluation because the DNAPL is located 30 ft below ground surface and approximately 20 ft below the water table. Technologies currently available for the treatment of PCBs in soil do not appear to be practical for the *in situ* treatment of soil saturated with DNAPL at depth, below the water table. Large scale excavation was not considered to be practical, as a portion of the DNAPL extends beneath the plant buildings, and would disrupt plant operations. Also, given that the DNAPL is a liquid and contains PCB concentrations greater than 500 parts per million (ppm), the treatment technology required by the Toxic Substances Control Act (TSCA) is incineration. In consideration of these factors, it is considered unlikely that, treatment of the DNAPL using currently available technologies, either *in situ* or *ex situ*, would be feasible at this site.

With these issues in mind, the institutional, containment, collection and collection enhancement general response actions were considered. Table 1 lists the general response actions and the associated technologies and process options evaluated for inclusion in the development of remedial alternatives for DNAPL recovery. Based on this evaluation, the most favorable process options of each technology type were chosen as representative process options. A summary of this evaluation and selected representative process options are presented in Table 1. As shown on the table with asterisks (*), the following process options were retained for inclusion in the development of DNAPL recovery alternatives:

- sheet piling with sealable joints
- vertical extraction wells
- horizontal extraction wells
- interceptor trench
- steam injection

DNAPL recovery alternatives
By combining the process options listed above, four alternatives were developed to address the DNAPL. The No Further Action Alternative was also included. The following paragraphs describe each of the alternatives developed and presents conceptual designs for each.

DNAPL Recovery Alternative 1 - No Further Action. The No Further Action Alternative comprises continued monitoring and collection of DNAPL from ORW-1 and ORW-2. Monitoring for DNAPL would be conducted by routine ground water sampling in down gradient wells with analysis for PCBs and VOCs. Samples would be collected from monitoring wells within the recoverable DNAPL area, as well as down gradient, to monitor for DNAPL. It has been assumed that the current ground water monitoring well configuration would be sufficient to conduct the DNAPL monitoring. It has also been assumed that the activities described in this alternative are currently being performed, and would continue to be performed in the future with implementation with any of the remaining alternatives evaluated in this FS. A cost estimate for the activities associated with this alternative has not been prepared as costs for these activities are included in the site-wide no further action alternative.

DNAPL Recovery Alternative 2 - Containment/Collection. This alternative includes the use of a containment barrier that would also function to collect DNAPL. This containment barrier would be a rectangular interceptor trench located across the width of the DNAPL plume, along the down gradient edge of the recoverable DNAPL (Figure A-1). A profile view of this alternative is presented in Figure A-2.

The containment/collection trench would be constructed of steel sheet piling with sealable joints driven to an approximate elevation of 220 feet above mean sea level (amsl), which is approximately 5 feet below the lowest elevation that DNAPL has been observed at the site. Penetration to this depth would key the bottom of the sheet piling approximately 5 to 10 feet into the low permeability layer upon which the DNAPL has been observed. After installation of the sheet piling, the interior of the trench would be excavated with a long-stick excavator or a crane equipped with a clam shell bucket. The excavated trench would be approximately 150 feet long, 30 feet deep, and 4 feet wide. Excavated soil containing PCBs at concentrations of concern would be transported off-site for appropriate disposal. For the purposes of this evaluation, it has been assumed that soil below the water table would require management as PCB-containing material. The upgradient side of the trench would be screened from the top of the low permeability layer to the top of the DNAPL pool (approximately 2.5 feet). The joints of the sheet piling would be sealed along the downgradient side of the trench.

The bottom of the trench would be sloped to the northeast to form a collection point for DNAPL that migrates into the trench through the screened area. Collected DNAPL would be pumped to the existing ORW-2 oil storage building through double walled PVC pipe equipped with a leak detection system, and handled in a manner which is consistent with the procedures currently performed at ORW-2. The existing oil storage facility is equipped with a level sensor and related system control which deactivates the pump when the drum approaches full. When full, drums are transported to the GE Fort Edward RCRA storage facility and subsequently shipped off-site for incineration. For the purposes of this FS, it has been assumed that PVC piping would be compatible with the DNAPL. PVC is expected to be compatible with PCBs, however, the DNAPL contains approximately 1% TCE. PVC is not recommended for conveying pure TCE, however, a one percent concentration is not expected to significantly degrade PVC. Other piping materials that are more compatible with TCE, such as high density polyethylene (HDPE) would likely be evaluated during final design.

Research conducted by USEPA indicates that reducing the hydrostatic pressure within DNAPL extraction wells relative to the hydrostatic pressure outside the extraction wells can improve the recoverability of DNAPL. A pilot study could be conducted to evaluate the effect of reducing the head (i.e., removal of the standing water above the DNAPL zone within a well or trench) on the DNAPL recovery rate. The well or trench screen would be placed only in the DNAPL. Evacuation of water within the sump or well down to the screened interval would create a lower head within the sump or well. This lower head may increase DNAPL flow into the well. The results of this pilot study would allow a cost-benefit analysis of performing DNAPL collection enhancement in this manner. If advantageous, the recovery system could be designed to include pumps to remove the water in the trench or wells.

Ground water entering the trench could be maintained at a level just above the DNAPL pool with a level-controlled pumping system. Collected water would be pumped through doubled walled PVC piping equipped with a leak detection system to GE's existing water treatment facility (WTF). This piping would also be installed below the frost line. The resultant head differential should enhance DNAPL migration into the trench. The trench would be covered with steel plating flush with the existing grade, with an access door to allow monitoring and maintenance activities.

It is difficult to evaluate the relative effectiveness and costs of each alternative without developing an estimate of the total volume of DNAPL that would be recovered, and the rate of recovery. It should be noted that the recovery rates estimated in this FS are intended as a means of comparing alternatives; the actual DNAPL recovery rates may vary significantly from those estimated for purposes of this FS. The mobility of subsurface DNAPL, and the capacity of the soil for retaining non-mobile DNAPL is not fully understood. To facilitate the evaluation of alternatives and preparation of cost estimates, assumptions have been developed. These assumptions are based on field data, which indicate that the recoverable DNAPL is within an area approximately 230 feet long by 110 feet wide, and the DNAPL layer is approximately 2.5 feet thick. The porosity of the soil is assumed to be 30% (O'Brien & Gere, 1994), and the DNAPL retention capacity of the soil is 20% (Cohen & Mercer, 1993). These assumptions allow estimation of the total volume of DNAPL within the area (142,000 gallons), with approximately 114,000 gallons of this total estimated as being recoverable.

To provide a basis for estimating DNAPL recovery rates for each of the DNAPL recovery alternatives, historical recovery rates from ORW-2 have been evaluated. The oil recovery rate observed in ORW-2 has been reasonably consistent from 1992 through 1995, with recovery rates ranging from approximately 2.5 to 3.5 gallons per week (Figure A-3). The surface area of the screen within the DNAPL in ORW-2 is approximately 2.6 square feet (4-inch diameter by 2.5 feet high). The ratio between the volume of DNAPL recovered and the surface area of the screen exposed to the DNAPL in ORW-2 has been calculated, and has been subsequently applied to the surface area of the screen exposed to the DNAPL by each alternative to estimate an initial rate of recovery. Even though the recovery rate observed in ORW-2 has been reasonably consistent, it is expected that the rate of DNAPL recovery resulting from each alternative will decrease with time as DNAPL head decreases. As this rate of decrease is difficult to predict, it has been assumed that an average DNAPL recovery rate for the life of each alternative will be 50% of the initial recovery rate. This average recovery rate has been used to develop cost estimates for each alternative.

The approximate surface area of the screen within the DNAPL presented by the containment/collection trench would be approximately 375 square feet. The average recovery rate per unit of surface area observed in ORW-2 is estimated to be 3 gallons per week per 2.6 square feet of screen. If this ORW-2 recovery rate per unit of screen surface area is assumed to be applicable to the containment/collection trench screen area, approximately 62 gallons of DNAPL would be collected per day initially. For the purposes of cost estimation, an average DNAPL recovery rate of 31 gallons per day has been assumed for Alternative 2. If it is further assumed that the total volume of recoverable DNAPL is approximately 114,000 gallons, a recovery rate of 31 gallons per day would collect this material in approximately 10 years. It should be noted that the recovery of DNAPL in the collection trench would require that DNAPL located in the northwest portion of the recoverable DNAPL plume travel a distance of approximately 230 feet over the estimated 10 years of operation of Alternative 2. It is not known whether this is reasonable. It has been assumed that the existing oil storage and handling system can be utilized for this alternative. If the volume of DNAPL actually recovered exceeds what can be practically handled in drums, a tank trailer could be used to store collected DNAPL temporarily until transport off-site for disposal. A containment structure beneath the tanker would be required.

DNAPL Recovery Alternative 3 - Vertical Extraction Wells. This alternative would consist of forty-eight vertical extraction wells (forty-seven new, and continued use of ORW-2) to recover the DNAPL. The recovery wells would be installed in the recoverable DNAPL plume (Figure A-4), providing a well field located on a grid with a triangular spacing of approximately 25 feet. The design of the recovery wells would be similar to ORW-2, except that the screened interval would be placed only in the DNAPL zone and cased above the DNAPL to the ground surface. An oil recovery system similar to the QED system currently in use in ORW-2 would be installed in each well. The compressed air system for the oil recovery pumps would be centralized. The recovery systems would be connected through common headers (one for air and one for DNAPL) laid in trenches below the frost line. DNAPL piping would consist of double walled PVC piping equipped with a leak detection system. The electrical controls would also be routed underground through shallow trenches. Based on recovery rates observed in ORW-2, it is estimated that approximately 21 gallons of DNAPL per day would be collected initially with this system. For the purposes of cost estimation, an average DNAPL recovery rate of 10.5 gallons per day has been assumed. Based on the assumed volume of recoverable DNAPL stated previously, a recovery rate of 10.5 gallons per day would collect this material in approximately 30 years. It is assumed that the existing DNAPL storage facilities, electrical system, and current DNAPL handling and disposal procedures could be utilized for the expanded recovery system.

DNAPL Recovery Alternative 4 - Horizontal Extraction Wells. This alternative would utilize two horizontal extraction wells to collect DNAPL. The conceptual layout of the horizontal recovery wells is illustrated in Figure A-5. One horizontal well would be located along the downgradient edge of the recoverable DNAPL to intercept migrating DNAPL. The other horizontal well would be located parallel to the direction of DNAPL migration, along the approximate centerline of the plume. The horizontal wells would act as an underdrain system.

A conceptual profile view of the horizontal well installation is illustrated in Figure A-6. Horizontal wells are typically installed by initiating drilling at an angle a distance from the point at which the well is to be horizontal. This distance is determined by the desired depth of the well and the turning radius capability of the type of drilling equipment employed. Typically for horizontal wells 30 feet below the surface, the entry point would be approximately 100 feet prior to the desired point of horizontal orientation. The horizontal portion of the boring would extend to the end point of the desired screened portion of the well, and then would angle upward and intersect the ground surface approximately 100 feet beyond the end of the well screen.

Pumping equipment can be installed into the well from the surface. The accuracy of locating horizontal wells is a function of the depth of the well, and is approximately two percent of the depth of the well (i.e., a well installed horizontally 30 below the ground surface can be located within approximately 0.6 feet). The wells would be screened along the horizontal length of the well, through the recoverable DNAPL. As the surface of the low permeability layer appears to be uneven, portions of the well will likely be several inches above or below the bottom of the DNAPL layer. This condition will likely impact the effectiveness of the horizontal wells for collection of DNAPL.

Both horizontal wells would be sloped (if possible) to provide a reservoir for accumulated DNAPL at one end prior to angling the boring back toward the ground surface (Figure A-6). An oil recovery system similar to the QED system currently in use in ORW-2 would be installed in each well. The compressed air system would be centralized. The recovery systems would be connected through common headers (one for air and one for DNAPL) laid in trenches below the frost line. DNAPL piping would consist of double walled PVC piping equipped with a leak detection system. The electrical controls would also be routed underground through shallow trenches.

As stated previously, the surface area of screen within the DNAPL in ORW-2 is approximately 2.6 feet. The surface area of screen within the DNAPL presented by the two 6-inch diameter horizontal wells depicted in Figure A-5 would be approximately 600 square feet. If the recovery rate per unit surface area of screen observed in ORW-2 is assumed to be applicable to the horizontal wells, approximately 98 gallons of DNAPL would be collected per day. However, this recovery rate may be reduced due to loss of screen contact with the DNAPL in areas where the well is installed in the underlying low permeability layer. The recovery rate will also decrease with time as DNAPL would have to migrate further to enter the collection system. Therefore, for the purposes of cost estimation, is has been assumed that an average of 49 gallons of DNAPL would be collected per day. Based on the assumed volume of recoverable DNAPL stated previously, a recovery rate of 49 gallons per day would collect this material in approximately 6.4 years. It has been assumed that the existing oil storage facilities, electrical entrance, and current DNAPL handling and disposal procedures could be utilized for this alternative. As discussed previously, developing an accurate estimate of the DNAPL recovery rate is difficult. If the volume of DNAPL actually recovered exceeds what can be practically handled in drums, a tank trailer could be used to store collected DNAPL temporarily until transport off-site for disposal. A containment structure beneath the tanker would be required.

This alternative is inherently flexible, in that if, based on operational data, additional horizontal or vertical wells desired to enhance recovery, additional wells could be installed. Likewise, if it was decided that a downgradient barrier could be useful to reduce DNAPL migration and/or enhance recovery, a barrier wall could be placed southeast of the DNAPL plume.

DNAPL Recovery Alternative 5 - Containment with Enhanced Collection. This alternative is an expanded version of Alternative 2. In addition to the containment/collection trench located at the downgradient end of the recoverable DNAPL, two horizontal collection wells would be installed along the top of the low permeability layer, and eighteen vertical wells equipped with a heat exchange system would be installed. The approximate configuration of this alternative is presented in Figure A-7. Subsurface information developed during the site RI (O'Brien & Gere, 1997) indicates that the surface of the low permeability layer is uneven, and does not have a consistent slope. Therefore, it is assumed that the horizontal wells would be installed without slope at an elevation corresponding to the lower areas of the top of the low permeability layer (approximate elevation 232 amsl), and screened throughout the length of the DNAPL plume. These horizontal collection wells would be intercepted by the containment/collection trench. DNAPL that accumulated in the horizontal wells would drain into the containment/collection trench where it would be pumped and managed as described for Alternative 2.

Increasing the temperature of the DNAPL will reduce viscosity, and thereby potentially increase the rate of collection. The approximate viscosity of the DNAPL (at an estimated subsurface temperature 50°F) is approximately 500 saybolt universal seconds (SUS). Viscosity as a function of temperature for site DNAPL and Aroclor 1242 is presented in Figure A-8. The SUS units of viscosity measurement are used to define the viscosity of oils, including automotive lubricating oil. This figure demonstrates the impact of increased temperature on the viscosity of the DNAPL. An increase in temperature from 50 to 130°F reduces the viscosity by approximately a factor of three.

As part of this alternative, steam would be cycled through vertical heat exchange wells installed to heat the recoverable DNAPL. The GE Fort Edward plant has an excess steam production capacity of approximately 6,000 lbs/hr at 180 psi. As the subsurface temperature increases, the less viscous DNAPL would flow more readily toward the horizontal collection wells and the containment/collection sump, where it would be collected and managed. The steam would be cycled through heat exchanged installed in eighteen vertical wells (Figure A-7). These wells would consist of 4-inch PVC casings, screened from the top of the low permeability layer to the top of the water table (approximately 20 feet). A loop heat exchange system consisting of ¾-inch diameter copper tubing would be installed in each well. A header system would connect the wells at the surface to the plant steam system. The horizontal wells would collect the mobilized DNAPL, with subsequent discharge to the containment/collection sump.

An evaluation was performed to estimate the amount of heat (in the form of steam) that would be required to increase and maintain an elevated temperature within the recoverable DNAPL. A heat loss evaluation is presented in Attachment B. For the purposes of the heat loss analysis, the area of the recoverable DNAPL has been assumed to be 230 feet long by 110 feet wide by 2.5 feet deep. The heat loss analysis indicates that approximately 2.30 million BTUs would be required to increase the temperature of this area 1°F. Additionally, the heat loss from the heated mass is estimated to be approximately 8,600 BTUs per hour per °F above the ambient temperature of the soil. Therefore, based on these data, raising the temperature of the soil and DNAPL within the recoverable DNAPL area from 50 to 130°F would require approximately 185 million BTUs or 185,000 pounds of steam. To counteract the anticipated heat loss, an estimated 690,000 BTUs per hour (690 pounds of steam per hour) would be required to maintain the temperature in the recoverable DNAPL area. With a constant input of 1.5 million BTUs (1,500 pounds of steam) per hour, it is estimated that the recoverable DNAPL area would reach the target temperature of 130°F in approximately 10 days. Upon reaching this temperature, the steam input could be reduced to approximately 690 pounds per hour to maintain 130°F in the targeted area.

For the purposes of preparing a cost estimate, it has been assumed that reducing the viscosity by a factor of three would triple the rate of DNAPL collection. This assumption makes it possible that 200 to 300 gallons of DNAPL could be collected per day. For the purposes of cost estimation, it has been assumed that an average of 100 gallons of DNAPL would be collected per day. Based on the assumed volume of recoverable DNAPL stated previously, a recovery rate of 100 gallons per day would collect this material in approximately 3.1 years. It has been assumed that the existing oil storage facilities, electrical entrance, and current DNAPL handling and disposal procedures could be utilized for this alternative. However, if recovery rates this high were actually realized, a tank trailer would be used to store the DNAPL temporarily until transport off-site for disposal. A containment structure beneath the tanker would be required.

Cost analyses for DNAPL recovery

Tables A-2 through A-5 detail the estimated costs associated with Alternatives 2 through 5, respectively. The objective of these cost estimates is to make comparative analyses based on cost. Cost estimates were prepared using readily available vendor information and quotations, cost estimating guides, experience, and assumptions pertaining to DNAPL recovery rates. Capital costs are those required to implement a remedy and include both direct and indirect capital costs. Annual O&M costs are costs which are expected to be incurred yearly throughout implementation of the remedy. In addition, costs will be incurred for management of recoverable DNAPL. The estimated capital, annual DNAPL management, and annual O&M costs are presented for each alternative along with a total present worth cost, which represents the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action. Present worth costs were calculated based on the estimated time for recovery, as discussed in the remedial alternative descriptions. This equates to a 10, 30, 6.4, and 3.1-year life for Alternatives 2, 3, 4 and 5, respectively, at a 5% discount rate.

Since no additional construction or operation is included for Alternative 1, there would be no capital costs associated with this alternative. As stated previously, a cost estimate was not prepared for Alternative 1 as it is assumed that the activities associated with this alternative would be performed as part of each of the other alternatives, if implemented.

Comparative analysis of DNAPL recovery alternatives

As discussed previously, evaluation and comparison of the DNAPL recovery alternatives is difficult due to several factors. These factors include:

- uncertainty relating to estimating the amount of recoverable DNAPL and the rate of DNAPL collection accomplished by each alternative, including initial DNAPL collection rates and expected decreases in collection rates over time
- uncertainty relating to the mobility of the DNAPL, as it pertains to the rate of DNAPL movement toward collection points and identification of zones of influence for collection devices
- uncertainty relating to the actual shape of the surface of the low permeability layer beneath the DNAPL layer and identification of the optimum location for the DNAPL collection devices for each alternative and the ability to construct the devices in that location
- uncertainty as to the nature of present and future DNAPL migration patterns at the site (if any).

The alternatives have been evaluated on a qualitative basis. This evaluation has focused on identification and discussion of the advantages and disadvantages of implementation of each alternative, and cost. The results of this analysis are summarized on Table A-6.

Recommended DNAPL recovery alternative

Based on the evaluation performed above, DNAPL Alternative 4 has been selected to be incorporated into the site wide remedial alternatives. DNAPL Alternative 4 has the lowest estimated direct capital cost, and can be easily supplemented with additional components as the project proceeds and field data becomes available. It should be noted, however, that horizontal wells, such as those included in DNAPL Alternative

4, are not a well proven technology for DNAPL collection, and are subject to the uncertainties described above. In particular, accurate location of the horizontal wells along the sand/low permeability layer interface is likely critical to long term success. Additionally, if subsurface conditions do not allow installation of the wells on a slope, efficiency of DNAPL recovery may be reduced. Other potential disadvantages for DNAPL Alternative 4 include a longer DNAPL travel distance to the point of collection (approximately four times as far as it is for DNAPL Alternative 3), and DNAPL Alternative 4 may not provide the degree of physical containment provided by DNAPL Alternative 2, which combines physical containment and DNAPL collection. These potential deficiencies can be at least partially mitigated by the collection of additional data, use of a pilot approach, selection and implementation of improvements (if required) to the system as field data becomes available, and integration into the site wide remedial alternatives.

References

Cohen, Robert M. and James W. Mercer. 1993. DNAPL Site Evaluation. CK Smoley/CRC Press. Boca Raton, Florida.

Dunn Geoscience Corporation. 1990. On-Site Remedial Plan, prepared for General Electric Company, Fort Edward, New York. July 1990.

General Electric Company. 1995. Research and Development Program for the Destruction of PCBs, Fourteenth Progress Report, August 1, 1994 - July 31, 1995. September 1995.

Lawler, Matusky & Skelly Engineers (LMS). 1985. Revised Remedial Investigation Report, GE Capacitor Plant, Fort Edward, New York. December 1985.

Lawler, Matusky & Skelly Engineers. 1988. Feasibility Study Off-Site, Shallow Aquifer, GE Capacitor Plant, Fort Edward, New York. January 1988.

Lawler, Matusky & Skelly Engineers. 1989. Revised On-Site Feasibility Study, GE Capacitor Plant, Fort Edward, New York. May 1989.

Monsanto Company. ND. The Aroclors - Physical Properties and Suggested Applications. Application data bulletin No. O-P-115.

NYSDEC 1985

O'Brien & Gere Engineers, Inc., 1994. DNAPL Recovery Well Evaluation. October 1994.

O'Brien & Gere Engineers, Inc., 1997. Remedial Investigation Report. January 1997.

TABLES

Table A-1

GENERAL ELECTRIC COMPANY
Fort Edward Facility
DNAPL Collection Evaluation

EVALUATION OF PROCESS OPTIONS FOR DNAPL COLLECTION

General Response Action	Remedial Technology	Process Option	Description	Effectiveness	Implementability	Cost
No Further Action	None	Not Applicable.	No further action. Includes continued operation of oil recovery well ORW-2 and periodic monitoring of DNAPL using existing wells located both in and downgradient of the recoverable DNAPL plume.	Not effective method of reducing effect of DNAPL migration on ground water potentially migrating off-site.	Readily Implementable.	No capital costs. No additional O&M costs.
Institutional Actions	Monitoring	DNAPL Monitoring*	Periodic sampling and analysis of DNAPL.	Effective method for monitoring change in DNAPL thickness and contaminant concentrations over time. Useful for evaluating remedy effectiveness.	Readily Implementable.	No additional capital costs. No additional O&M costs.
Containment Actions	Flow Diversion	Slurry Wall	Constructed in a vertical trench under a slurry of clay-like material. Slurry is most commonly a mixture of bentonite and water. Excavation and likely off-site disposal of 40,000 cy of soil would be required.	Effective method of preventing migration of DNAPL beyond wall. Effectiveness may be reduced over time if DNAPL affects permeability of slurry.	Implementable.	High capital costs associated with excavation and disposal of soil. Low O&M costs.
		Vibrated Beam Wall	Constructed by vibrating beams into ground and injecting sealant down annulus of beams, creating a low permeability wall without excavation of soil.	Effectively prevents migration of DNAPL beyond wall with no soil removed for surface disposal. However, slight deflection of beams potentially causes impermeability to be compromised. Site soils (sand) may increase potential for beam deflection.	Implementable.	Medium capital cost associated with beam driving and sealant injection. Low O&M costs.
		Jet Grout Wall	Constructed by high pressure injection of grout down bore holes spaced ⅓ to 1 ft apart, creating a wall of grout without excavation of soil.	Effectively prevents migration of DNAPL beyond wall with minimal soil removal for surface disposal. Effectiveness may be reduced over time if DNAPL affects permeability of grout.	Implementable.	High capital cost associated with drilling 450 boreholes. Low O&M costs.
		Auger Mix Wall	Constructed by using a soil mixing auger to mix soil with slurry *in situ*.	Effectively prevents migration of DNAPL beyond wall with minimal soil removed. Effectiveness may be reduced over time if DNAPL affects permeability of slurry.	Implementable.	High capital costs associated with equipment mobilization. Low O&M costs.
		Steel Sheet Piling	Constructed by driving steel sheets into ground using electric hammer vibration or diesel hammers, without excavation of soil.	Effectively prevents migration of majority of DNAPL beyond sheet piles with no earth material removed from the ground. However, potential exists for seepage of DNAPL past the joints in the sheet piling.	Implementable.	Medium capital costs. Medium O&M costs.
		Steel Sheet Piling with Sealable Joints*	Constructed by driving steel sheets into ground using electrical hammer vibration or direct hammers. Larger annulus joints are grouted with sealant, thereby reducing the permeability of the wall.	Effectively prevents migration of DNAPL beyond sheet piles with no earth material removed from the ground and little or no potential for seepage between joints.	Implementable.	Medium capital costs. Low O&M costs.

* Representative Process Option

Table A-1

GENERAL ELECTRIC COMPANY
Fort Edward Facility
DNAPL Collection Evaluation

EVALUATION OF PROCESS OPTIONS FOR DNAPL COLLECTION

General Response Action	Remedial Technology	Process Option	Description	Effectiveness	Implementability	Cost
Collection Actions	Extraction	Vertical Extraction Wells*	Installation of vertical shallow unconsolidated extraction wells to pump and collect DNAPL.	Effectively collects DNAPL for removal. Currently used at site with degree of success.	Readily Implementable.	Medium capital costs. Medium O&M costs.
		Horizontal Extraction Wells*	Installation of horizontal shallow unconsolidated extraction wells to pump and collect DNAPL.	Ptentially effective means of collecting DNAPL. Potentially more effective than vertical wells due to increased screen length exposed to DNAPL.	Implementable.	High capital cost associated with drilling. Medium O&M costs.
	Interception	Interceptor Trenches*	Constructed by excavating a trench designed to collect DNAPL.	Effectively prevents migration of DNAPL beyond trench and effectively collects DNAPL flowing into trench.	Readily Implementable.	High capital costs associated with excavation and disposal of overlying soil. Low O&M costs.
Collection Enhancement Actions	Injection	Surfactant Injection	Injection of surfactant to subsurface to increase DNAPL mobility and recovery potential.	Potentially effective means to enhance DNAPL recovery. Surfactant reduces interfacial tensions or increases contaminant solubility to improve DNAPL extractability. Potential for uncontrolled migration of DNAPL and surfactant through unconsolidated/clay transition zone. Pilot study necessary.	Moderately Implementable.	Medium capital costs associated with installation of injection wells. High O&M costs associated with surfactant injection, collection and recycling.
		Hot Air Injection	Injection of hot air to subsurface to elevate temperatures and vapor pressure which would increase DNAPL mobility and recovery potential.	Potentially effective means to enhance DNAPL recovery. Effectively reduces DNAPL viscosity and interfacial tension through increased temperature to improve extractability. Potential for uncontrolled mobilization of DNAPL through unconsolidated/clay transition zone. Pilot study is necessary.	Implementable.	Medium capital costs associated with installation of injection wells. High O&M costs associated with continued hot air injection and collection.
		Steam Injection*	Injection of steam to subsurface to elevate temperature and vapor pressure which would increase DNAPL mobility and recovery potential..	Potentially effective means to enhance DNAPL recovery. Effectively reduces DNAPL viscosity and interfacial tension through increased temperature to improve extractability. Potential for uncontrolled mobilization of DNAPL through unconsolidated/clay transition zone.	Readily Implementable. Excess steam available at plant.	Medium capital costs associated with installation of injection wells. Medium O&M costs associated with continued steam injection and collection.
		Co-Solvent Injection	Injection of co-solvents into subsurface to increase DNAPL mobility and recovery potential.	Effectiveness not known. Technology in research stage and has not been proven for an application of this nature.	Implementable.	Medium capital costs associated with installation of injection wells. High O&M costs associated with co-solvent injection, collection and recycling.

* Representative Process Option

Table A-2

GENERAL ELECTRIC COMPANY
Fort Edward Facility
DNAPL Collection Evaluation

COST ESTIMATE - ALTERNATIVE 2

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
DIRECT CAPITAL COSTS				
CONTAINMENT/COLLECTION SUMP				
Steel Sheet Piling with Sealed Joints (40 ft high)	12320	SF	$26.00	$320,320
Bracing	Lump Sum	Lump Sum	$25,000	$25,000
Soil Excavation	670	CY	$10.00	$6,700
Disposal of PCB-Contaminated Soil	582	TON	$225.00	$130,950
1" Steel Plating	600	SF	$20.00	$12,000
COLLECTION PUMP AND PIPING				
Submersible Water Pump with Level Control	1	EA	$2,000.00	$2,000
QED Pulse Pump including System Controls	1	EA	$3,378.00	$3,378
1" PVC Riser (Oil)	35	LF	$10.05	$352
2" PVC Riser (Water)	35	LF	$14.05	$492
2" Double Walled PVC with Leak Detection System	500	LF	$35.00	$17,500
Electrical service	200	LF	$9.00	$1,800
Soil Excavation for Installation Trenches	310	CY	$20.00	$6,200
OTHER COSTS				
Mobilization	Lump Sum	Lump Sum	$15,000	$15,000
Health & Safety	Lump Sum	Lump Sum	$20,000	$20,000
			Estimated Direct Capital Cost	$561,692
INDIRECT CAPITAL COSTS				
Contingency Allowance (25%)				$140,423
Engineering Fees (15%)				$84,254
Legal Fees (5%)				$28,085
			Estimated Indirect Capital Cost	$252,761
			TOTAL ESTIMATED CAPITAL COST	$814,453

Table A-2

GENERAL ELECTRIC COMPANY
Fort Edward Facility
DNAPL Collection Evaluation

COST ESTIMATE - ALTERNATIVE 2

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
ANNUAL DNAPL DISPOSAL COST				
(31 gpd x 365 days/ 55 gal/drum = 206 drums)				
55-gallon Collection Drums per Year	206	EA	$40.00	$8,240
Transportation of Drums to TSCA Facility (1800 miles)	206	DRUM	$15.00	$3,090
Disposal of PCB-Contaminated DNAPL	206	DRUM	$550.00	$113,300
ESTIMATED ANNUAL DNAPL DISPOSAL COST				$124,630
PRESENT WORTH OF ANNUAL DNAPL DISPOSAL COSTS FOR 10 YEARS (i=5%)				$962,360
ANNUAL OPERATING & MAINTENANCE COST				
Site Inspection (8 hours/month)	96	HRS	$50	$4,800
Oil Removal (1 hour/day)	365	HRS	$30	$10,950
Pump Replacement (1 pump every 4 years)	0.25	EA	$3,378	$845
Water Sampling (SPDES requirements once/month)	12	EA	$100	$1,200
Insurance (1% of Direct Capital Cost)				$8,145
Reserve Fund (1% Direct Capital Cost)				$8,145
ESTIMATED ANNUAL OPERATING & MAINTENANCE COST				$34,084
PRESENT WORTH OF ANNUAL OPERATING & MAINTENANCE COSTS FOR 10 YEARS (i=5%)				$263,184
DNAPL IRM ALTERNATIVE 2 TOTAL PRESENT WORTH COST ESTIMATE				$2,039,997

Table A-3

GENERAL ELECTRIC COMPANY
Fort Edward Facility
DNAPL Collection Evaluation

COST ESTIMATE - ALTERNATIVE 3

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
DIRECT CAPITAL COSTS				
VERTICAL COLLECTION WELLS AND RECOVERY SYSTEM				
Drilling and Well Installation (including Decon)	1536	LF	$44.00	$67,584
Disposal of PCB-Contaminated Drill Cuttings	78	TONS	$225.00	$17,550
4" PVC Riser	1392	LF	$24.00	$33,408
4" PVC Screen	144	LF	$27.00	$3,888
QED Pulse Pump including System Controls	48	EA	$3,378.00	$162,144
1/2" PVC Well Piping (Oil)	1000	LF	$8.55	$8,550
2" Double Walled PVC with Leak Detection System (Oil)	1500	LF	$20.00	$30,000
5 HP Air Compressor	1	EA	$1,085.00	$1,085
3/8" Braid-Reinforced PVC (Air)	1000	LF	$0.37	$370
2" Steel Pipe with Corrosion Protection (Air)	1500	LF	$28.50	$42,750
Electrical service	2000	LF	$9.00	$18,000
Soil Excavation for Installation Trenches	450	CY	$20.00	$9,000
Disposal of soil containing PCBs/VOCs	675	TONS	$225	$151,875
OTHER COSTS				
Mobilization	Lump Sum	Lump Sum	$15,000	$15,000
Health & Safety	Lump Sum	Lump Sum	$10,000	$10,000
			Estimated Direct Capital Cost	$571,204
INDIRECT CAPITAL COSTS				
Contingency Allowance (25%)				$142,801
Engineering Fees (15%)				$85,681
Legal Fees (5%)				$28,560
			Estimated Indirect Capital Cost	$257,042
			TOTAL ESTIMATED CAPITAL COST	$828,246

Table A-3

GENERAL ELECTRIC COMPANY
Fort Edward Facility
DNAPL Collection Evaluation

COST ESTIMATE - ALTERNATIVE 3

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
ANNUAL DNAPL DISPOSAL COST				
(10.5 gpd x 365 days/ 55 gal/drum = 70 drums)				
55-gallon Collection Drums per Year	70	EA	$40.00	$2,800
Trasportation of Drums to TSCA Facility (1800 miles)	70	Drums	$15.00	$1,050
Disposal of PCB-Contaminated DNAPL	70	Drums	$550.00	$38,500
ESTIMATED ANNUAL DNAPL DISPOSAL COST				$42,350
PRESENT WORTH OF ANNUAL DNAPL DISPOSAL COSTS FOR 30 YEARS (i=5%)				$651,023
ANNUAL OPERATING & MAINTENANCE COST				
Site inspection (16 hours/month)	192	HRS	$50	$9,600
Oil removal (2 hours/week)	104	HRS	$30	$3,120
Pump Replacement (3 pumps/year)	3	EA	$3,378	$10,134
Insurance (1% of Direct Capital Cost)				$8,282
Reserve Fund (1% Direct Capital Cost)				$8,282
ESTIMATED ANNUAL OPERATING & MAINTENANCE COST				$39,419
PRESENT WORTH OF ANNUAL OPERATING & MAINTENANCE COSTS FOR 30 YEARS (i=5%)				$605,965
DNAPL IRM ALTERNATIVE 3 TOTAL PRESENT WORTH COST ESTIMATE				$2,085,234

Table A-4

GENERAL ELECTRIC COMPANY
Fort Edward Facility
DNAPL Collection Evaluation

COST ESTIMATE - ALTERNATIVE 4

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
DIRECT CAPITAL COSTS				
HORIZONTAL COLLECTION WELLS AND RECOVERY SYSTEM				
Drilling and Well Installation (including Decon)	740	LF	$200	$148,000
Disposal of PCB-Contaminated Drill Cuttings	56	TONS	$225	$12,600
6" PVC Riser	400	LF	$27	$10,800
6" PVC Screen	340	LF	$30	$10,200
QED Pulse Pump including System Controls	2	EA	$3,378	$6,756
1/2" PVC Well Piping (Oil)	300	LF	$8.55	$2,565
2" Double Walled PVC with Leak Detection System (Oil)	225	LF	$35.00	$7,875
5 HP Air Compressor	1	EA	$1,085.00	$1,085
3/8" Braid-Reinforced PVC (Air)	200	LF	$0.37	$74
1" Steel Pipe with Corrosion Protection (Air)	225	LF	$17.05	$3,836
Electrical service	350	LF	$9.00	$3,150
Soil Excavation for Installation Trenches	100	CY	$20.00	$2,000
Disposal of soil containing PCBs/VOCs	150	TONS	$225	$33,750
OTHER COSTS				
Mobilization	Lump Sum	Lump Sum	$9,000	$9,000
Health & Safety	Lump Sum	Lump Sum	$10,000	$10,000
			Estimated Direct Capital Cost	$261,691
INDIRECT CAPITAL COSTS				
Contingency Allowance (25%)				$65,423
Engineering Fees (15%)				$39,254
Legal Fees (5%)				$13,085
			Estimated Indirect Capital Cost	$117,761
			TOTAL ESTIMATED CAPITAL COST	$379,452

Table A-4

GENERAL ELECTRIC COMPANY
Fort Edward Facility
DNAPL Collection Evaluation

COST ESTIMATE - ALTERNATIVE 4

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
ANNUAL DNAPL DISPOSAL COST				
(49 gpd x 365 days/ 55 gal/drum = 325 drums)				
55-gallon Collection Drums per Year	325	EA	$40.00	$13,000
Trasportation of Drums to TSCA Facility (1800 miles)	325	Drums	$15.00	$4,875
Disposal of PCB-Contaminated DNAPL	325	Drums	$550.00	$178,750
Estimated Annual DNAPL Disposal Cost				$196,625
PRESENT WORTH OF ANNUAL DNAPL DISPOSAL COST FOR 6.4 YEARS (i=5%)				$1,054,722
ANNUAL OPERATING & MAINTENANCE COST				
Site Inspection (8 hours/month)	96	HRS	$50	$4,800
Oil Removal (8 hours/week)	416	HRS	$30	$12,480
Pump Replacement (1 every 2 years)	0.5	EA	$3,378	$1,689
Insurance (1% of Direct Capital Cost)				$3,795
Reserve Fund (1% Direct Capital Cost)				$3,795
ESTIMATED ANNUAL OPERATING & MAINTENANCE COST				$26,558
PRESENT WORTH OF ANNUAL OPERATING & MAINTENANCE COSTS FOR 6.4 YEARS (i=5%)				$142,461
DNAPL IRM ALTERNATIVE 4 TOTAL PRESENT WORTH COST ESTIMATE				$1,576,636

Table A-5

GENERAL ELECTRIC COMPANY
Fort Edward Facility
DNAPL Collection Evaluation

COST ESTIMATE - ALTERNATIVE 5

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
DIRECT CAPITAL COSTS				
CONTAINMENT/COLLECTION SUMP				
Steel Sheet Piling with Sealed Joints (40 ft high)	6000	SF	$26.00	$156,000
Steel Sheet Piling without Sealed Joints (40 ft high)	6320	SF	$20.00	$126,400
Bracing	Lump Sum	Lump Sum	$25,000	$25,000
Soil Excavation	670	CY	$20.00	$13,400
Disposal of PCB-Contaminated Soil	1005	TON	$225.00	$226,125
1" Steel Plating	600	SF	$20.00	$12,000
COLLECTION PUMP AND PIPING				
Submersible Water Pump with Level Control	1	EA	$2,000.00	$2,000
Submersible High Viscosity Oil Pump with Level Control	1	EA	$3,378.00	$3,378
1" PVC Riser (Oil)	35	LF	$10.05	$352
2" PVC Riser (Water)	35	LF	$14.05	$492
2" Double Walled PVC with Leak Detection System	500	LF	$35.00	$17,500
Electrical service	200	LF	$9.00	$1,800
Soil Excavation for Installation Trenches	310	CY	$20.00	$6,200
Disposal of soil containing PCBs/VOCs	465	TONS	$225	$104,625
HORIZONTAL COLLECTION WELLS AND RECOVERY SYSTEM				
Drilling and Well Installation (including Decon)	900	LF	$200	$180,000
6" CPVC Riser	400	LF	$48	$19,200
6" CPVC Screen	500	LF	$55	$27,500
Disposal of PCB-Contaminated Drill Cuttings	68	TONS	$225	$15,300
HEAT EXCHANGE SYSTEM				
Drilling and Well Installation	480	LF	$44.00	$21,120
Disposal of PCB-Contaminated Drill Cuttings	12	TONS	$225.00	$2,700
4" PVC Well Riser	435	LF	$19.05	$8,287
3/4" Copper Tubing	720	LF	$7.10	$5,112
3" Steel Header Piping	1200	LF	$50.00	$60,000
Soil Excavation for Installation Trenches	350	CY	$20.00	$7,000
Disposal of soil containing PCBs/VOCs	525	TONS	$225	$118,125
Steam for Initial Heating	360	1000 LBS	$7.00	$2,520
OTHER COSTS				
Mobilization	Lump Sum	Lump Sum	$32,000	$32,000
Health & Safety	Lump Sum	Lump Sum	$25,000	$25,000
			Estimated Direct Capital Cost	$1,219,135

Table A-5

GENERAL ELECTRIC COMPANY
Fort Edward Facility
DNAPL Collection Evaluation

COST ESTIMATE - ALTERNATIVE 5

ITEM	QTY	UNITS	UNIT COST	TOTAL COST
INDIRECT CAPITAL COSTS				
Contingency Allowance (25%)				$304,784
Engineering Fees (15%)				$182,870
Legal Fees (5%)				$60,957
			Estimated Indirect Capital Cost	$548,611
			TOTAL ESTIMATED CAPITAL COST	$1,767,746
ANNUAL DNAPL DISPOSAL COST				
(100 gpd x 365 days/ 55 gal/drum = 664 drums)				
55-gallon Collection Drums per Year	664	EA	$40.00	$26,560
Trasportation of Drums to TSCA Facility (1800 miles)	664	DRUM	$15.00	$9,960
Disposal of PCB-Contaminated DNAPL	664	DRUM	$550.00	$365,200
			ESTIMATED ANNUAL DNAPL DISPOSAL COST	$401,720
			PRESENT WORTH OF ANNUAL DNAPL DISPOSAL COST FOR 3.1 YEARS (i=5%)	$1,127,763
ANNUAL OPERATING & MAINTENANCE COST				
Steam (690 lbs/hr)	6044.4	1000 LBS	$7.00	$42,311
Site Inspection (6 hours/week)	312	HRS	$50	$15,600
Oil Removal (10 hours/week)	520	HRS	$30	$15,600
Pump Replacement (1 every 2 years)	0.5	EA	$3,378	$1,689
Insurance (1% of Direct Capital Cost)				$17,677
Reserve Fund (1% Direct Capital Cost)				$17,677
			ESTIMATED ANNUAL OPERATING & MAINTENANCE COST	$110,555
			PRESENT WORTH OF ANNUAL OPERATING & MAINTENANCE COSTS FOR 3.1 YEARS (i=5%)	$310,364
			DNAPL IRM ALTERNATIVE 5 TOTAL PRESENT WORTH COST ESTIMATE	$3,205,874

Table A-6. Alternative analysis summary.

Alternative	Advantages	Disadvantages	Estimated Cost					
			Total Capital	Annual DNAPL Disposal	Annual O&M	Present Worth of Annual DNAPL Disposal	Present Worth of Annual O&M	Total Present Worth
Alternative 1 - NoFurther Action	• Easily implemented • Low operation and maintenance costs	• Migration of DNAPL not controlled beyond what is accomplished by ORW-2 • Magnitude of source not reduced beyond what is accomplished by ORW-2.	--	--	--	--	--	--
Alternative 2 - Containment/ Collection	• Implemented using standard contruction techniques • DNAPL migration controlled • Migrating DNAPL collected • Magnitude of source reduced (~ 31 gal./day) • Low system operation and maintenance costs (operation of 1 pump)	• DNAPL recovery passive • Relatively long migration distance to collection point. • Excavation and disposal of soil required. • Relatively high capital cost.	$814,453	$124,630	$34,084	$962,360 (10 years)	$263,184 (10 years)	$2,039,997 (10 years)
Alternative 3 - Vertical Extraction Wells	• Implemented using standard drilling and construction techniques • Technology currently used to collect DNAPL at site • Ability to install screen at clay/DNAPL interface accurately • Magnitude of source reduced (~ 10 gal./day)	• Low recovery rates based on historical site recovery data • DNAPL not physically contained and may continue to migrate • Low screen area to DNAPL ratio (compared to horizontal wells • High system operation and maintenance costs (operation of 48 pumps)	$828,246	$42,350	$39,419	$651,023 (30 years)	$605,965 (30 years)	$2,085,234 (30 years)
Alternative 4 - Horizonal Extraction Wells	• High screen area to DNAPL ratio • More efficient DNAPL collection than vertical wells • Low system operation and maintenance costs (operation of 2 pumps) • Magnitude of source reduced (~ 49 gal./day) • Easily upgraded with additional horizontal wells	• Technology only recently applied to environmental projects • DNAPL not physically contained and may continue to migrate • Accurate location of horizontal well screen critical • Uneven surface of low permeability layer makes installation at constant slope difficult • Accuracy of location limited to approximately 2% of depth	$379,452	$196,625	$26,558	$1,054,722 (6.4 years)	$142,461 (6.4 years)	$1,576,636 (6.4 years)
Alternative 5 - Containment with Enhanced Collection	• Recoverable DNAPL contained • Migrating DNAPL collected • Aggressive DNAPL collection • Magnitude of source reduced (~ 100 gal./day)	• High operation and maintenance costs (associated with steam) • Efficiency of collection cannot be estimated accurately • Mobilized less viscous DNAPL may migrate beyond existing limits.	$1,767,746	$401,720	$110,555	$1,127,763 (3.1 years)	$310,364 (3.1 years)	$3,205,874 (3.1 years)

FIGURES

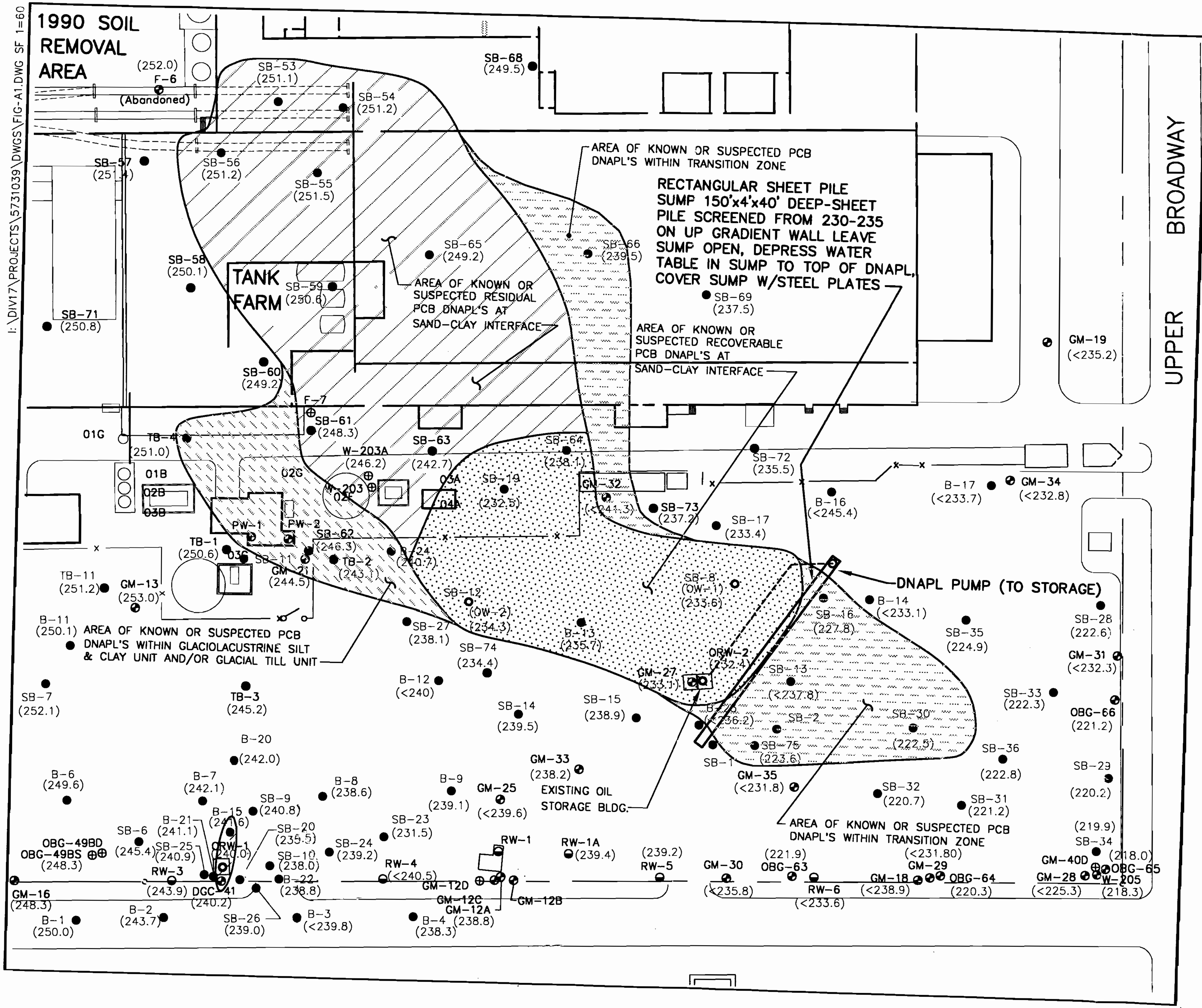


FIGURE A-1

LEGEND

SB-28 ● SOIL BORING LOCATION
GM-31 MONITORING WELL LOCATION
RW-6 RECOVERY WELL LOCATION
GM-12D ⊕ BEDROCK MONITORING WELL
ORW-2 ○ OIL RECOVERY WELL
(231.5) TOP OF LOW PERMEABILITY LAYER

GENERAL ELECTRIC CO.
FT. EDWARD FACILITY

ALTERNATIVE 2
CONTAINMENT/COLLECTION
CONCEPTUAL DESIGN

DNAPL COLLECTION
EVALUATION

60 0 60
SCALE IN FEET

FILE NO. 5731.039

O'BRIEN & GERE ENGINEERS, INC.

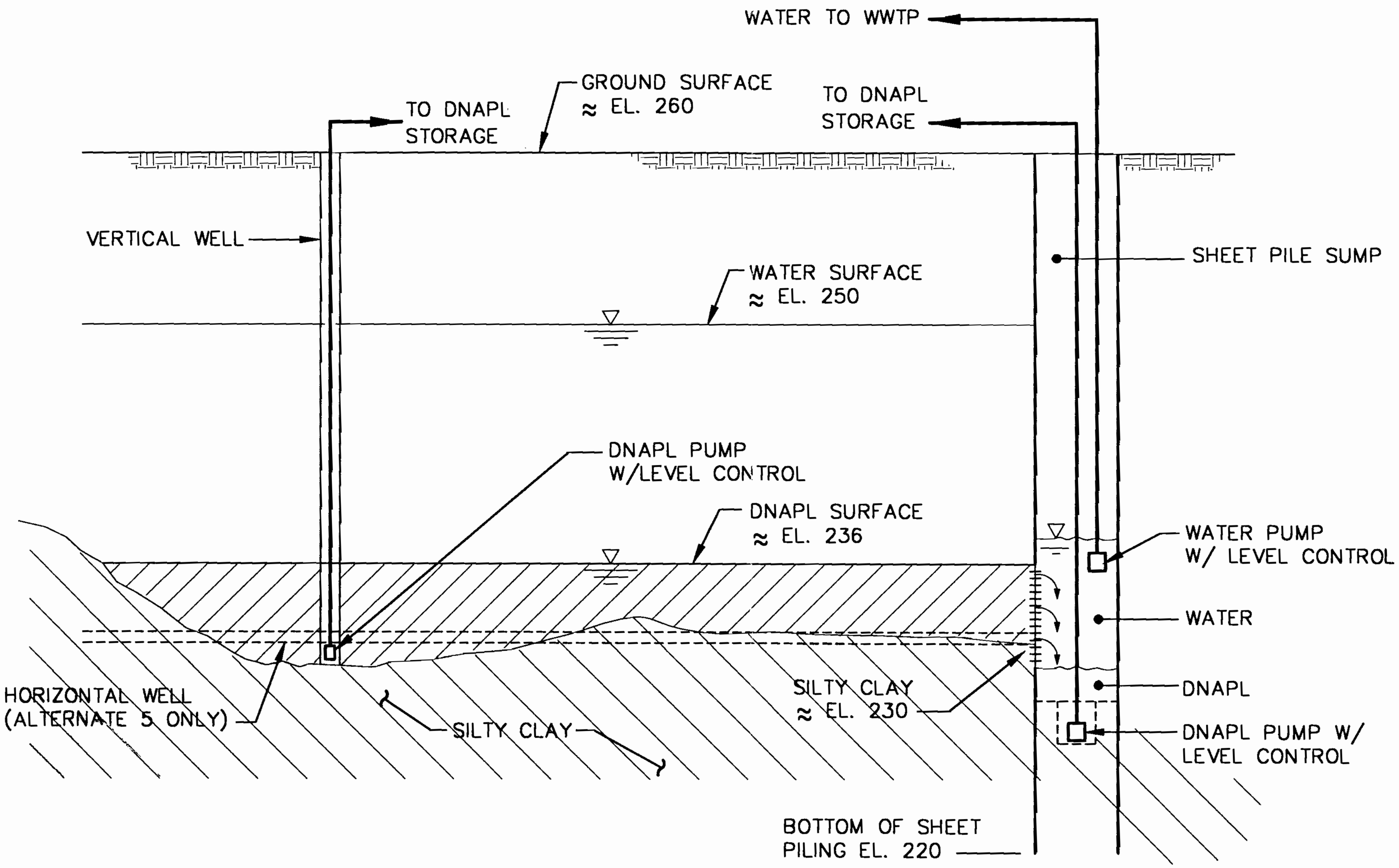


FIGURE A-2

GENERAL ELECTRIC CO.
FT. EDWARD FACILITY

ALTERNATIVE 2
CONTAINMENT/COLLECTION
CONCEPTUAL DESIGN

PROFILE VIEW

NOT TO SCALE

FILE NO. 5731.039

O'BRIEN & GERE ENGINEERS, INC.

I:\DIV17\PROJECTS\5731039\DWGS\FIG-A2.DWG SF 1=1

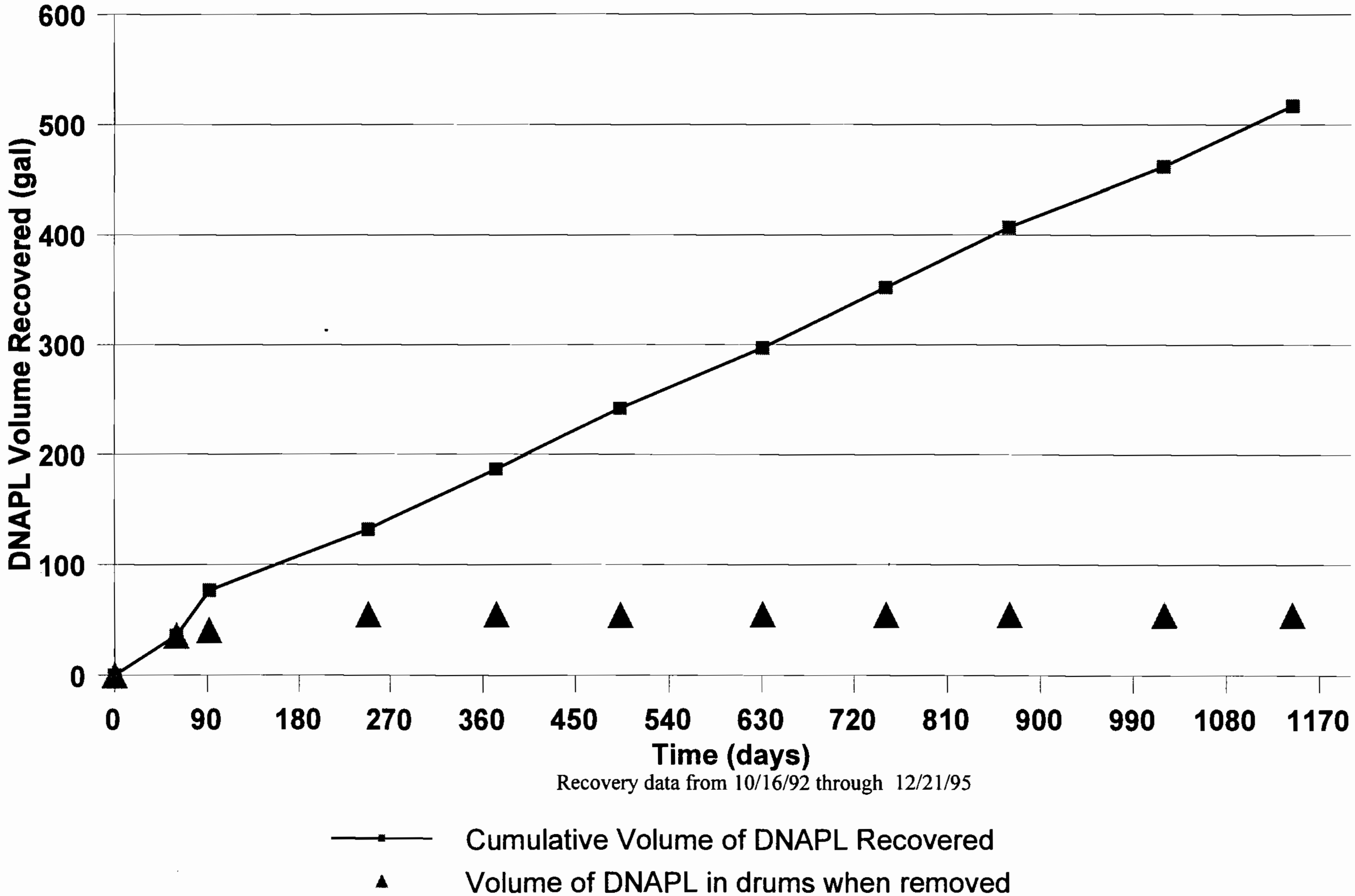
DATE: DECEMBER 13, 1996

I:\DIV17\PROJECTS\5731.039\DWG\ORW-2

FILE NO.

DNAPL RECOVERY EVALUATION

Historical DNAPL Recovery Rate in ORW-2



O'BRIEN & GERE ENGINEERS INC.

FIGURE A-3

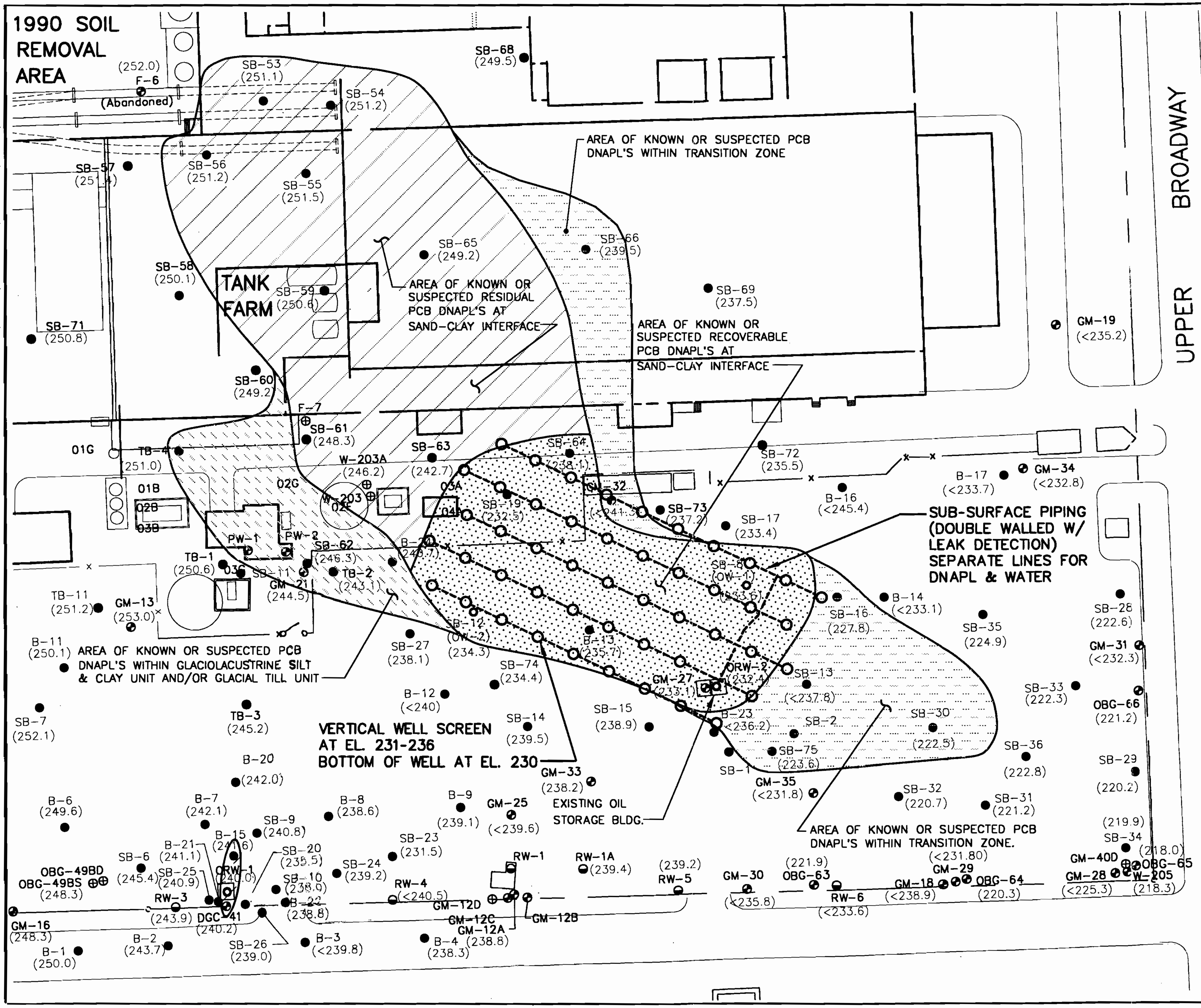


FIGURE A-4

LEGEND

- VERTICAL EXTRACTION WELL
- SB-28 SOIL BORING LOCATION
- GM-31 MONITORING WELL LOCATION
- RW-6 RECOVERY WELL LOCATION
- GM-12D BEDROCK MONITORING WELL
- ORW-2 OIL RECOVERY WELL
- (231.5) TOP OF LOW PERMEABILITY LAYER

GENERAL ELECTRIC CO.
FT. EDWARD FACILITY

ALTERNATIVE 3
VERTICAL EXTRACTION WELLS
CONCEPTUAL DESIGN

DNAPL COLLECTION
EVALUATION

60 0 60
SCALE IN FEET

FILE NO. 5731.039

O'BRIEN & GERE ENGINEERS, INC.

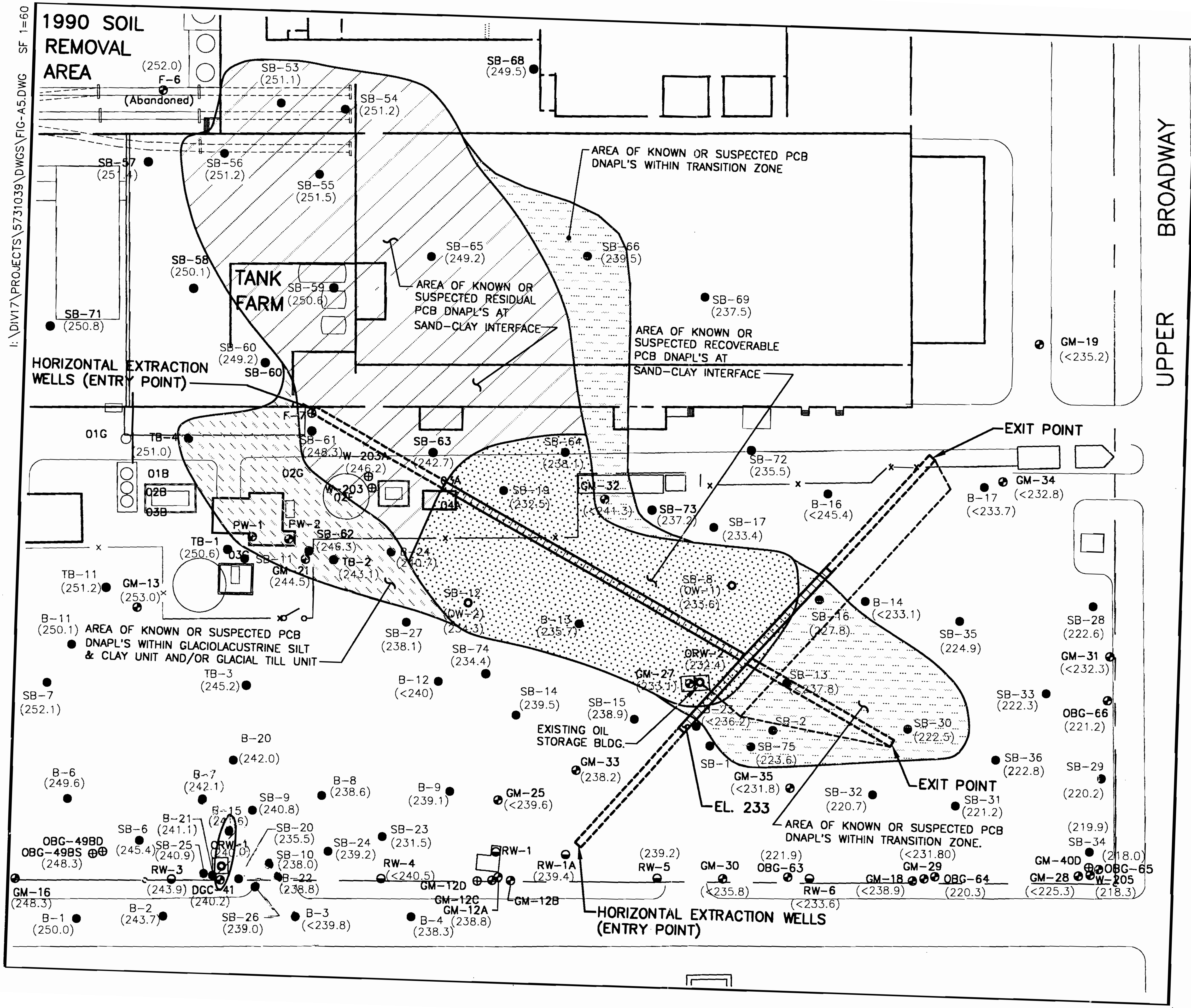


FIGURE A-5

LEGEND

- SB-28 ● SOIL BORING LOCATION
- GM-31 MONITORING WELL LOCATION
- RW-6 RECOVERY WELL LOCATION
- GM-12D ⊕ BEDROCK MONITORING WELL
- ORW-2 OIL RECOVERY WELL
- (231.5) TOP OF LOW PERMEABILITY LAYER

GENERAL ELECTRIC CO.
FT. EDWARD FACILITY

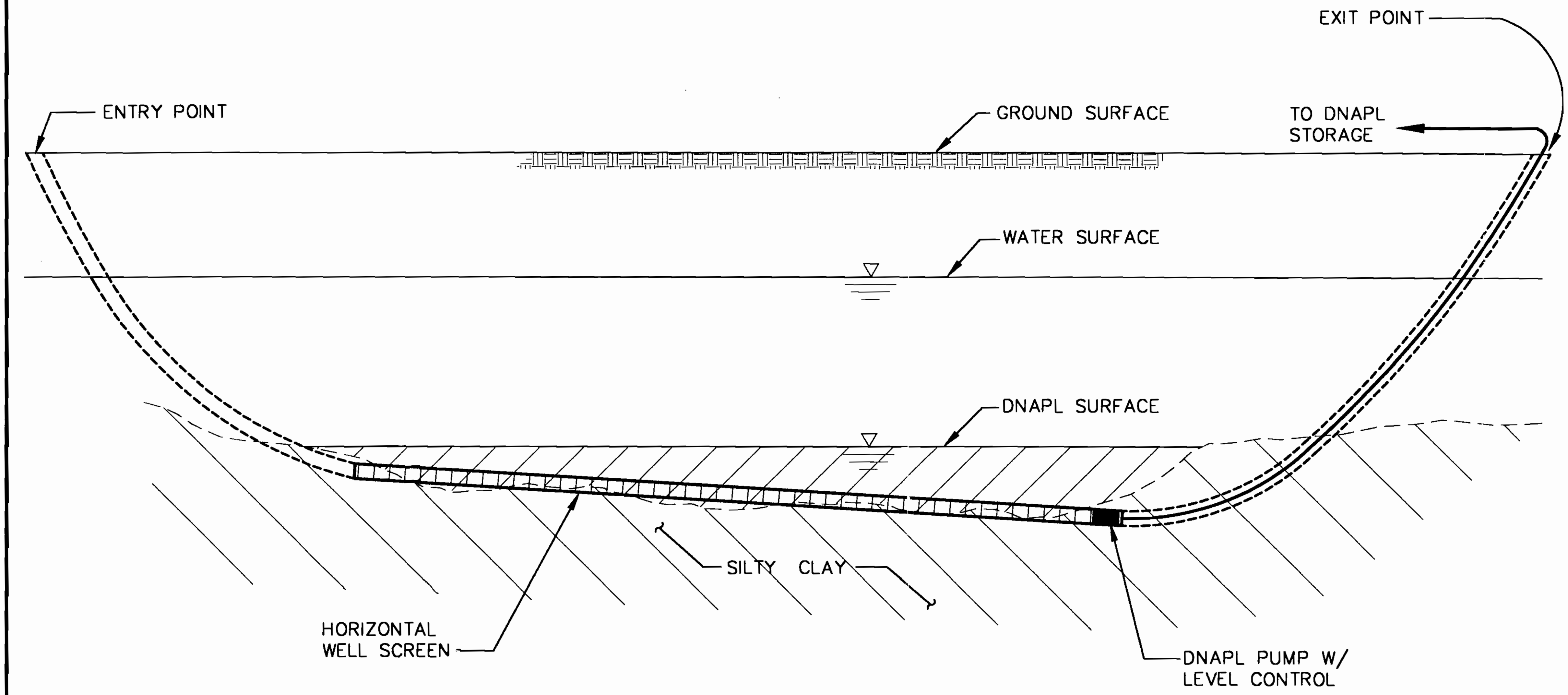
ALTERNATIVE 4
HORIZONTAL
EXTRACTION WELLS
CONCEPTUAL DESIGN

DNAPL COLLECTION
EVALUATION

60 0 60
SCALE IN FEET

FILE NO. 5731.039

O'BRIEN & GERE ENGINEERS, INC.



I:\DIV17\PROJECTS\5731039\DWGS\FIG-A6.DWG SF 1=1

FIGURE A-6

GENERAL ELECTRIC CO.
FT. EDWARD FACILITY

ALTERNATIVE 4
HORIZONTAL
EXTRACTION WELL
CONCEPTUAL DESIGN

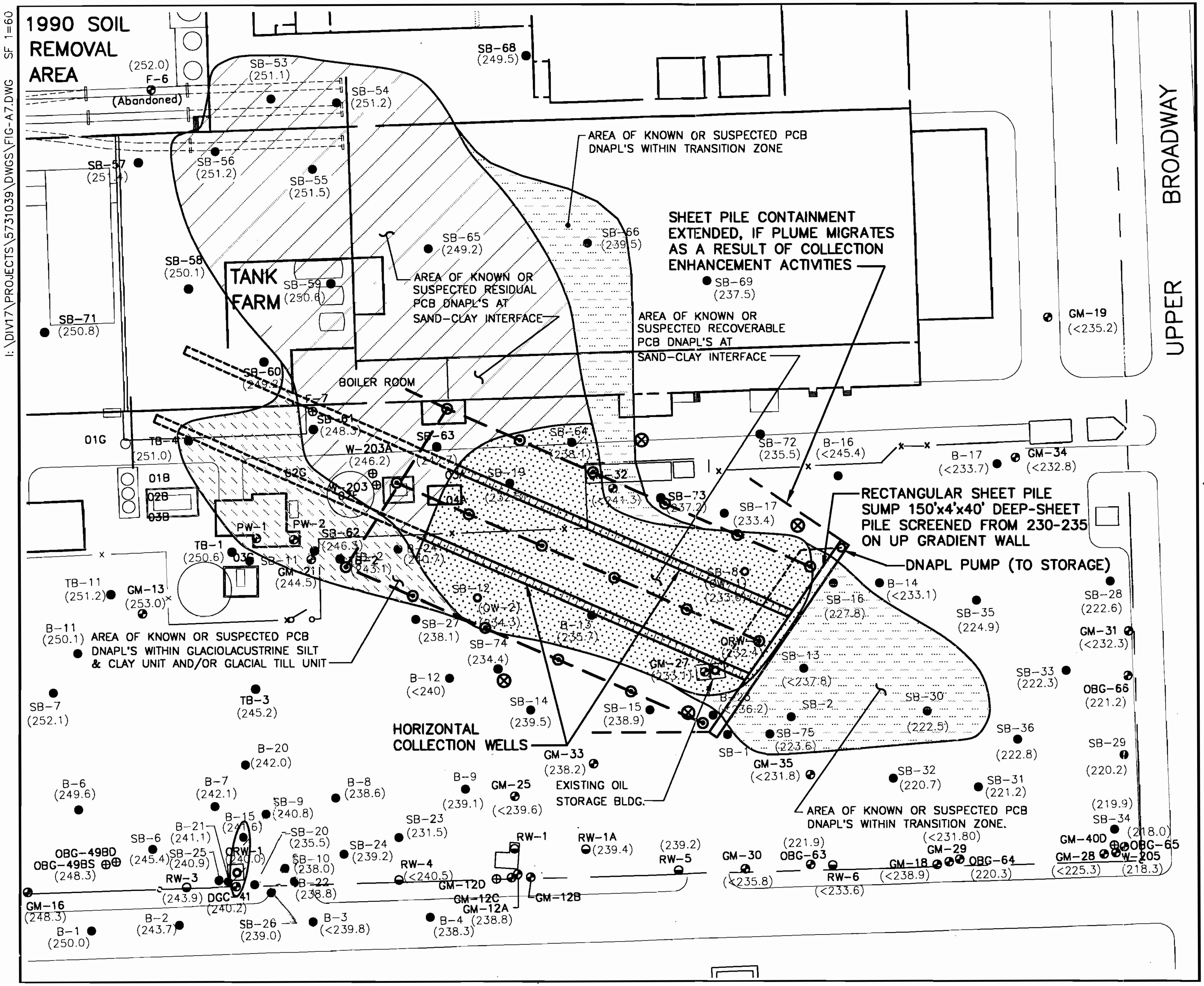
PROFILE VIEW

NOT TO SCALE

FILE NO. 5731.039

O'BRIEN & GERE ENGINEERS, INC.

FIGURE A-7



LEGEND

- ⊗ DNAPL MONITORING WELL
- SB-28 ● SOIL BORING LOCATION
- GM-31 MONITORING WELL LOCATION
- RW-6 RECOVERY WELL LOCATION
- GM-12D ⊕ BEDROCK MONITORING WELL
- ORW-2 OIL RECOVERY WELL
- STEAM INJECTION WELL
- (231.5) TOP OF LOW PERMEABILITY LAYER
- STEAM DISTRIBUTION PIPING

GENERAL ELECTRIC CO.
FT. EDWARD FACILITY

ALTERNATIVE 5
CONTAINMENT WITH
ENHANCED COLLECTION
CONCEPTUAL DESIGN

DNAPL COLLECTION
EVALUATION

60 0 60
SCALE IN FEET

FILE NO. 5731.039

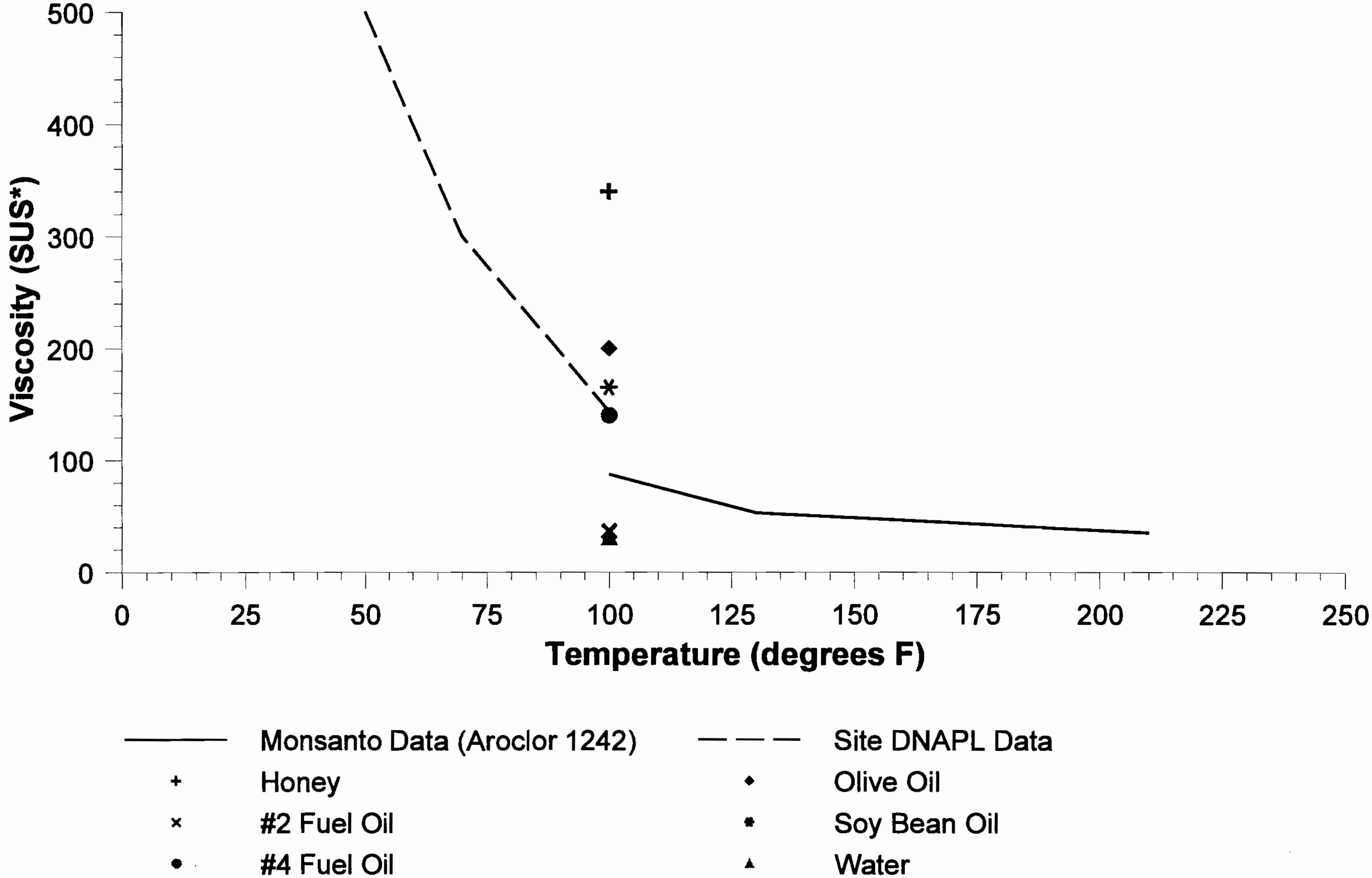
O'BRIEN & GERE ENGINEERS, INC.

I:\DIV17\PROJECTS\5731039\DWGS\FIG-A7.DWG SF 1=60

FILE NO.

DNAPL COLLECTION EVALUATION

DNAPL Viscosity/Temperature Relationship



* - Saybolt Universal Second

O'BRIEN & GERE ENGINEERS INC.

FIGURE A-8

ATTACHMENT A

NORTHEAST ANALYTICAL
ENVIRONMENTAL LAB SERVICES
301 Nott Street, Schenectady, NY 12305
(518) 346-4592 • FAX (518) 381-6055

CERTIFICATE OF ANALYSIS
OCTOBER 9, 1995

O'BRIEN & GERE ENGINEERS, INC.

5000 BRITTONFIELD PARKWAY
SUITE 300, PO BOX 4873
SYRACUSE, NY 13221
CONTACT: BILL AYLING

CUSTOMER ID:	DGC-41	NEA ID:	957892
SAMPLE MATRIX:	OIL	DATE SAMPLED:	09/29/95 TIME: 14:45
DATE RECEIVED:	09/29/95 TIME: 16:15	DATE TESTED:	10/06/95
SAMPLED BY:	CB, SL	LOCATION:	DNAPL INV FORT EDWARD
CUSTOMER PO#:	N/A	LAB ELAP #:	#11078

SW-846 METHOD 8080: POLYCHLORINATED BIPHENYLS

AROCLOR IDENTIFICATION	PCB CONCENTRATION {µg/g}
AROCLOR 1016	< 35000
AROCLOR 1221	< 35000
AROCLOR 1232	< 35000
AROCLOR 1242	1020000
AROCLOR 1248	< 35000
AROCLOR 1254	< 35000
AROCLOR 1260	< 35000
TOTAL PCB RESULTS > PQL	1020000

Authorized Signature: James Daly

Northeast Analytical, Inc.
Robert E. Wagner, Laboratory Director

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REW\CMS\100995

NY STATE DEPARTMENT OF HEALTH CERTIFIED LAB

NORTHEAST ANALYTICAL
ENVIRONMENTAL LAB SERVICES
301 Nott Street, Schenectady, NY 12305
(518) 346-4592 - FAX (518) 381-6055

CERTIFICATE OF ANALYSIS
OCTOBER 9, 1995

O'BRIEN & GERE ENGINEERS, INC.

5000 BRITTONFIELD PARKWAY
SUITE 300, PO BOX 4873
SYRACUSE, NY 13221
CONTACT: BILL AYLING

CUSTOMER ID:	ORW-2	NEA ID:	957893
SAMPLE MATRIX:	OIL	DATE SAMPLED:	09/29/95 TIME: 14:35
DATE RECEIVED:	09/29/95 TIME: 16:15	DATE TESTED:	10/06/95
SAMPLED BY:	CB, SL	LOCATION:	DNAPL INV FORT EDWARD
CUSTOMER PO#:	N/A	LAB ELAP #:	#11078

SW-846 METHOD 8080: POLYCHLORINATED BIPHENYLS

AROCLOR IDENTIFICATION	PCB CONCENTRATION {μg/g}
AROCLOR 1016	< 20000
AROCLOR 1221	< 20000
AROCLOR 1232	< 20000
AROCLOR 1242	826000
AROCLOR 1248	< 20000
AROCLOR 1254	187000
AROCLOR 1260	< 20000
TOTAL PCB RESULTS > PQL	1010000

Authorized Signature: James Daly

Northeast Analytical, Inc.
Robert E. Wagner, Laboratory Director

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REW\GMB\100995

NY STATE DEPARTMENT OF HEALTH CERTIFIED LAB

NORTHEAST ANALYTICAL
ENVIRONMENTAL LAB SERVICES
301 Nott Street, Schenectady, NY 12305
(518) 346-4592 • FAX (518) 381-6055

CERTIFICATE OF ANALYSIS
OCTOBER 13, 1995

O'BRIEN & GERE ENGINEERS, INC.
5000 Brittonfield Parkway
Suite 300, PO Box 4873
Syracuse, NY 13221
Contact: Mr. Bill Ayling

CUSTOMER ID:	DGC-41	NEA ID:	957892
SAMPLE MATRIX:	OIL	DATE SAMPLED:	09/29/95 TIME: 14:45
DATE RECEIVED:	09/29/95 TIME: 16:15	DATE TESTED:	10/12/95
SAMPLED BY:	CB, SL	LOCATION:	DNAPL INV. FORT EDWARD, NY
CUSTOMER PO#:	N/A	LAB ELAP #:	#11078

EPA METHOD 8240

PARAMETER PERFORMED	RESULTS	UNITS
DICHLORODIFLUOROMETHANE	< 77000	µg/kg
CHLOROMETHANE	< 77000	µg/kg
VINYL CHLORIDE	< 77000	µg/kg
BROMOMETHANE	< 77000	µg/kg
CHLOROETHANE	< 77000	µg/kg
TRICHLOROFLUOROMETHANE	< 77000	µg/kg
ACETONE	< 77000	µg/kg
1,1-DICHLOROETHENE	< 38000	µg/kg
CARBON DISULFIDE	< 38000	µg/kg
METHYLENE CHLORIDE	< 38000	µg/kg
TRANS-1,2-DICHLOROETHENE	< 38000	µg/kg
VINYL ACETATE	< 77000	µg/kg
1,1-DICHLOROETHANE	< 38000	µg/kg
2-BUTANONE	< 77000	µg/kg
CHLOROFORM	< 38000	µg/kg
1,1,1-TRICHLOROETHANE	190000	µg/kg
CARBON TETRACHLORIDE	< 38000	µg/kg
BENZENE	< 38000	µg/kg
TRICHLOROETHENE	6800000	µg/kg
1,2-DICHLOROPROPANE	< 38000	µg/kg
1,2-DICHLOROETHANE	< 38000	µg/kg
BROMODICHLOROMETHANE	< 38000	µg/kg
DIBROMOMETHANE	< 38000	µg/kg
2-CHLOROETHYLVINYLETHER	< 38000	µg/kg
4-METHYL-2-PENTANONE	< 77000	µg/kg
CIS-1,3-DICHLOROPROPENE	< 38000	µg/kg
TOLUENE	< 38000	µg/kg
TRANS-1,3-DICHLOROPROPENE	< 38000	µg/kg
2-HEXANONE	< 77000	µg/kg
1,1,2-TRICHLOROETHANE	< 38000	µg/kg
TETRACHLOROETHENE	< 38000	µg/kg
DIBROMOCHLOROMETHANE	< 38000	µg/kg
CHLOROBENZENE	< 38000	µg/kg
ETHYL BENZENE	< 38000	µg/kg
M&P XYLENE	< 38000	µg/kg
O-XYLENE	< 38000	µg/kg
STYRENE	< 38000	µg/kg
BROMOFORM	< 38000	µg/kg
1,1,2,2-TETRACHLOROETHANE	< 38000	µg/kg
1,3-DICHLOROBENZENE	< 38000	µg/kg
1,4-DICHLOROBENZENE	< 38000	µg/kg
1,2-DICHLOROBENZENE	< 38000	µg/kg
1,2-DIBROMO-3-CHLOROPROPANE	< 38000	µg/kg

Authorized Signature: James Daly

Northeast Analytical, Inc
Robert E. Wagner, Laboratory Director
NY STATE DEPARTMENT OF HEALTH CERTIFIED LAB

[illegible]
[illegible]

PHYSCIAL CHARATERISTIC ANALYTICAL RESULTS
DENSE NON-AQUEOUS PHASE LIQUID

General Electric Company
Fort Edward, New York

Sample Number Sample Date	ORW-1/DGC-41 12/13/95	OW-1/OW-2/ORW-2 12/13/95	Monsanto (12-95) (Aroclor 1242)	Monsanto (12-95) (Aroclor 1254)	Cohen & Mercer (1993) (Aroclor 1242)	Cohen & Mercer (1993) (Aroclor 1254)
Interfacial Tension @23°C (DuNuoy Tensiometer)	9.94 dynes/cm	16.54 dynes/cm	---	---	---	—
Density at Room Temperature (20°C)	1.324 g/mL	1.302 g/mL	1.378 g/mL @ 25°C	1.536 g/mL @ 25°C	1.392 [a] @ 20°C	1.505 [a] @ 20°C
Brookfield Viscosity:			16 - 19 (centistokes)	390 - 540 (centistokes)		
2°C	420 cps	380 cps				
10°C	134 cps	134 cps				
20°C	96 cps	80 cps			24 (centipoise @ 20°C)	700 (centipoise @ 20°C)
40°C	48 cps	42 cps	22-26 cps @ 25°C	599-829 cps @ 25°C		
Aqueous Solubility:			—	---	200	50
1mL Oil in 100 mL Water	Insoluble	Insoluble				
2mL Oil in 100 mL Water	Insoluble	Insoluble				
5mL Oil in 100 mL Water	Insoluble	Insoluble				

Notes:

1. All analyses performed by International Testing Laboratories in Newark, New Jersey.
2. cm designates centimeters
3. g designates grams
4. mL designates milliliters
5. cps designates centipoise per second
6. Interfacial Tension performed using ASTM-1331.
7. Density performed using ASTM-D1217.
8. Brookfield Viscosity performed using ASTM D-2849.
9. Aqueous Solubility Guideline performed using ASTM-D2030.
10. "a" indicates a relative density at 20°C which is defined as the density of a compound at a reference temperature, usually 20°C, divided by the density of water, usually at 4°C. Relative Density was formerly called Specific Gravity. This term is unitless.

PHYSCIAL CHARATERISTIC ANALYTICAL RESULTS
DENSE NON-AQUEOUS PHASE LIQUID

General Electric Company
Fort Edward, New York

Sample Number Sample Date	Rizwanul et al. 1974 (Aroclor 1254)	LMS Dec-95	Paris et al. (1978)	Tucker et al. (1975)	Mackay & Wolkoff (1973)	Nisbet & Sarofin (1972)
Interfacial Tension @23°C (DuNuoy Tensiometer)	—	—	---	—	—	—
Density at Room Temperature	---	---	---	—	---	---
Brookfield Viscosity: 2°C 10°C 20°C 40°C	—	---	—	---	---	---
Aqueous Solubility:	56 Room	244 +/- 31 19°C - 22°C	340 +/- 60 25 +/- °C	200 Room	240 25°C	200 20°C

Notes:

1. All analyses performed by International Testing Laboratories in Newark, New Jersey.
2. cm designates centimeters
3. mL designates milliliters
4. cps designates centipoise per second
5. Interfacial Tension performed using ASTM-1331.
6. Density performed using ASTM-D1217.
7. Brookfield Viscosity performed using ASTM D-2849.
8. Aqueous Solubility Guideline performed using ASTM-D2030.

Phone: (201) 589-4772
FAX # (201) 589-8485

INTERNATIONAL TESTING LABORATORIES

Material Testing and Consulting Engineers

REPORT OF TEST

No. 593018, 593019 **Date:** January 15, 1996

From O'Brien & Gere
22 Computer Drive West
Albany, New York 12205

Attn: Janet Forsell

Samples: Transormer Oil ORW-1/DGC-41 (Lab.#593018)
Transformer OIl OW-1/OW-2/ORW-2 (Lab.#593019)

Ref. No: O'Brien & Gere 5731.031

Required:
1. Interfacial Tension
2. Density
3. Aqueous Solubility
4. Brookfield Viscosities

Results:

PARAMETER	LAB NO. 593018	LAB NO. 593019
1. Interfacial Tension (DIH_2O) ASTM-D1331:23°C. DuNuoy Tensiometer	9.94 dynes per cm	16.54 dynes per cm
2. Density	1.324 gms/ml	1.302 gms/ml
3. Aqueous Solubility Guide Line: ASTM-D2030	a) 1 ml ~~H_2O~~ oil in 100 ml ~~oil~~ H_2O gave a very slightly cloudy appearance b) 2 ml ~~H_2O~~ oil in 100 ml ~~oil~~ H_2O gave same as above	a) 1 ml ~~H_2O~~ oil in 100 ml ~~oil~~ H_2O gave a very slightly cloudy appearance b) 2 ml ~~H_2O~~ oil in 100 ml ~~oil~~ H_2O gave same as above

See corrected report attached 1/22/96

To: O'Brien & Gere
Albany, New York

INTERNATIONAL TESTING LABORATORIES
[signature]
Martin M. Sackoff, Ph.D. Executive Director

Phone: (201) 589-4772
FAX # (201) 589-8485

INTERNATIONAL TESTING LABORATORIES

Material Testing and Consulting Engineers

REPORT OF TEST

No. **593018, 593019** **Date:** January 22, 1996

From O'Brien & Gere
22 Computer Drive West
Albany, New York 12205

Attn: Janet Forsell

Samples: Transformer Oil ORW-1/DGC-41 (Lab.#593018)

Transformer Oil OW-1/OW-2/ORW-2 (Lab.#593019)

Ref. No.: O'Brien & Gere 5731.031

Results:

Brookfield Viscosities at 2°C:

Sample	Viscosity
593018	420 cps
593019	380 cps

To: O'Brien & Gere
Albany, New York

INTERNATIONAL TESTING LABORATORIES

Martin M. Sackoff, Ph.D, Executive Director

578-582 MARKET STREET, NEWARK, NJ 07105-2913

NORTHEAST ANALYTICAL
ENVIRONMENTAL LAB SERVICES
301 Nott Street, Schenectady, NY 12305
(518) 346-4592 • FAX (518) 381-6055

CERTIFICATE OF ANALYSIS
OCTOBER 13, 1995

O'BRIEN & GERE ENGINEERS, INC.
5000 Brittonfield Parkway
Suite 300, PO Box 4873
Syracuse, NY 13221
Contact: Mr. Bill Ayling

CUSTOMER ID:	ORW-2	NEA ID:	957893
SAMPLE MATRIX:	OIL	DATE SAMPLED:	09/29/95 TIME: 14:35
DATE RECEIVED:	09/29/95 TIME: 16:15	DATE TESTED:	10/12/95
SAMPLED BY:	CB, SL	LOCATION:	DNAPL INV. FORT EDWARD, NY
CUSTOMER PO#:	N/A	LAB ELAP #:	#11078

EPA METHOD 8240

PARAMETER PERFORMED	RESULTS	UNITS
DICHLORODIFLUOROMETHANE	< 76000	µg/kg
CHLOROMETHANE	< 76000	µg/kg
VINYL CHLORIDE	< 76000	µg/kg
BROMOMETHANE	< 76000	µg/kg
CHLOROETHANE	< 76000	µg/kg
TRICHLOROFLUOROMETHANE	< 76000	µg/kg
ACETONE	< 76000	µg/kg
1,1-DICHLOROETHENE	< 38000	µg/kg
CARBON DISULFIDE	< 38000	µg/kg
METHYLENE CHLORIDE	< 38000	µg/kg
TRANS-1,2-DICHLOROETHENE	< 38000	µg/kg
VINYL ACETATE	< 76000	µg/kg
1,1-DICHLOROETHANE	< 38000	µg/kg
2-BUTANONE	< 76000	µg/kg
CHLOROFORM	< 38000	µg/kg
1,1,1-TRICHLOROETHANE	< 38000	µg/kg
CARBON TETRACHLORIDE	< 38000	µg/kg
BENZENE	< 38000	µg/kg
TRICHLOROETHENE	13000000	µg/kg
1,2-DICHLOROPROPANE	< 38000	µg/kg
1,2-DICHLOROETHANE	< 38000	µg/kg
BROMODICHLOROMETHANE	< 38000	µg/kg
DIBROMOMETHANE	< 38000	µg/kg
2-CHLOROETHYLVINYLETHER	< 38000	µg/kg
4-METHYL-2-PENTANONE	< 76000	µg/kg
CIS-1,3-DICHLOROPROPENE	< 38000	µg/kg
TOLUENE	< 38000	µg/kg
TRANS-1,3-DICHLOROPROPENE	< 38000	µg/kg
2-HEXANONE	< 76000	µg/kg
1,1,2-TRICHLOROETHANE	< 38000	µg/kg
TETRACHLOROETHENE	< 38000	µg/kg
DIBROMOCHLOROMETHANE	< 38000	µg/kg
CHLOROBENZENE	< 38000	µg/kg
ETHYL BENZENE	< 38000	µg/kg
M&P XYLENE	< 38000	µg/kg
O-XYLENE	< 38000	µg/kg
STYRENE	< 38000	µg/kg
BROMOFORM	< 38000	µg/kg
1,1,2,2-TETRACHLOROETHANE	< 38000	µg/kg
1,3-DICHLOROBENZENE	< 38000	µg/kg
1,4-DICHLOROBENZENE	130000	µg/kg
1,2-DICHLOROBENZENE	120000	µg/kg
1,2-DIBROMO-3-CHLOROPROPANE	< 38000	µg/kg

Authorized Signature: James Daly

Northeast Analytical, Inc
Robert E. Wagner, Laboratory Director

NY STATE DEPARTMENT OF HEALTH CERTIFIED LAB

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ren\obg\101395

Phone: (201) 589-4772
FAX # (201) 589-8485

INTERNATIONAL TESTING LABORATORIES

Material Testing and Consulting Engineers

REPORT OF TEST

No. 593018, 593019 **Date: January 15, 1996**

From O'Brien & Gere
Albany, New York 12205

Results: (continued)

PARAMETER	**LAB NO. 593018**	**LAB NO. 593019**
3. Aqueous Solubility Guide Line: ASTM-D2030	c) 5 ml ~~H_2O~~ 0:1 in 100 ml ~~oil~~ H_2O gave a slightly cloudy appearance	c) 5 ml ~~H_2O~~ 0:1 in 100 ml ~~oil~~ H_2O gave a slightly cloudy appearance
4. Brookfield Viscosities:		
10°C	134 cps	134 cps
20°C	96 cps	80 cps
40°C	48 cps	42 cps

see corrected report 1/22/96

To: O'Brien & Gere
Albany, New York

INTERNATIONAL TESTING LABORATORIES

Martin B. Sackoff, Ph.D. Executive Director

578-582 MARKET STREET, NEWARK, NJ 07105-2913

PERCENT CONCENTRATIONS OF CONSTITUENTS IN DENSE NON-AQUEOUS PHASE LIQUID ANALYTICAL RESULTS

General Electric Company
Fort Edward, New York

Sample Number Sample Date	DGC-41 9/29/95	ORW-2 9/29/95
Polychlorinated Biphenyls		
Aroclor 1242	102%	82.6%
Aroclor 1254	<3.5%	18.7%
Volatile Organic Compunds		
1,1,1-Trichloroethane	0.019%	<0.004%
Trichloroethene	0.680%	1.3%
1,4-Dichlorobenzene	<0.004%	0.013%
1,2-Dichlorobenzene	<0.004%	0.012%

Notes:

1. Analyses performed by Northeast Analytical, Inc.
2. The percentage of Aroclor 1242 for sample DGC-41 is greater than 100 due to laboratory variability.

mhc\50\fed-031\densresu.xls

FAX # (201) 589-8485

INTERNATIONAL TESTING LABORATORIES

Material Testing and Consulting Engineers

REPORT OF TEST

No. 593018, 593019 **Date:** January 22, 1996

From O'Brien & Gere
22 Computer Drive West
Albany, New York 12205

Attn: Janet Forsell

Ref No.: O'Brien & Gere 5731.031

Reference: ITL Report of January 15, 1996

Purpose: Correction : Aqueous Solubility:

SAMPLE 593018

a) 1 ml Oil in 100 ml H_2O gave a very slightly cloudy appearance

b) 2 ml Oil in 100 ml H_2O gave same as above

c) 5 ml Oil in 100 ml H_2O gave a slightly cloudy appearance

SAMPLE 593019

a) 1 ml Oil in 100 ml H_2O gave a very slightly cloudy appearance

b) 2 ml Oil in 100 ml H_2O gave same as above

c) 5 ml OIl in 100 ml H_2O gave a slightly cloudy appearance

To: O'Brien & Gere Engineers, Inc
Albany, New York

INTERNATIONAL TESTING LABORATORIES

Martin M. Sackoff, Ph.D. Executive Director

ATTACHMENT B

ATTACHMENT B

Calculations for: **Heat Requirements to Raise Temperature of DNAPL Saturated Soil**
and **Heat Loss from Heated DNAPL Saturated Soil**

DNAPL plume in fine-grained sands

Physical Parameters:

Soil density	=	1700 kg/m^3 (GE)
DNAPL density	=	1350 kg/m^3 (Monsanto)
Specific heat of soil (c_{soil})	=	1.05 kJ/kg °C (GE)
Specific heat of DNAPL (c_{DNAPL})	=	0.3 cal/g°C = 1.26 kJ/kg °C (Monsanto)
Porosity of soil	=	0.4 (assumed)
Plume dimensions	=	110 ft x 230 ft X 2.5 ft = 63,250 ft^3

63,250 ft^3 of DNAPL saturated soil

63,250 ft^3 x 0.4 = 25,300 ft^3 of pore volume = DNAPL volume

$$63{,}250 \text{ ft}^3 \times \frac{\text{m}^3}{35.3145 \text{ ft}^3} \times 1700 \frac{\text{kg}}{\text{m}^3} = 3{,}044{,}783 \text{ kg of soil} = m_{soil}$$

$$25{,}300 \text{ ft}^3 \times \frac{\text{m}^3}{35.3145 \text{ ft}^3} \times 1350 \frac{\text{kg}}{\text{m}^3} = 967{,}167 \text{ kg of DNAPL} = m_{DNAPL}$$

Calculate heat requirement to raise temperature of DNAPL saturated soil

Assume average subsurface temperature of 50°F ≅ 10°C
Assume heat DNAPL saturated soil to 130°F ≅ 54°C

Heat requirement = mc ΔT

Heat requirement for soil: Heat $= m_{soil}\, c_{soil}\, \Delta T$
= 3,044,783 kg (1.05 kJ/kg°C)(44°C)
= 140,668,975 kJ

Heat requirement for DNAPL: Heat $= m_{DNAPL}\, c_{DNAPL}\, \Delta T$
= 967,167 kg (1.26 kJ/kg°C)(44°C)
= 53,619,738 kJ

[**Total heat requirement = Heat requirement for soil + Heat requirement for DNAPL**
= 194,288,713 kJ
= 184,302,273 Btu]

Calculate heat loss from heated DNAPL saturated soil

Heat loss = KS $(T_1 - T_2)$

K	=	thermal conductivity
S	=	Shape factor
$(T_1 - T_2)$	=	130°F - 50°F = 80°F

From *Engineering Heat Transfer* by William S. Janna - The shape factor for an isothermal rectangular parallel pipe buried in a semi-infinite medium plot that has an isothermal surface.

$$S = 1.685 L [\log(1 + \frac{d}{w})]^{-59} x (\frac{d}{h})^{-0.078}$$

L	=	DNAPL saturated soil length	=	230 ft
w	=	DNAPL saturated soil width	=	110 ft
h	=	DNAPL saturated soil height	=	2.5 ft
d	=	distance to T_2; to be conservative, it was assumed that d = 1 ft.		

$$S = 1.685(230)[\log(1 + \frac{1}{110})]^{-0.59}(\frac{1}{2.5})^{-0.078}$$

$$= 1.685\ (230)\ (26.3)\ (1.074) = 10{,}947 \text{ ft}$$

Thermal conductivity value (K) for water saturated soil; take a mass weighted average:

For 1 ft^3 of soil = 106 lb
Also have 0.4 ft^3 of water x 62.4 lb/ft^3 = 25 lb
Total mass = 131 lb
Soil mass fraction = 0.81 = y_{soil}
Water mass fraction = 0.19 = y_{water}

$$K_{soil} = 10.5 \frac{Btu \cdot in}{hr\ ft^2\ °F} = \frac{0.875\ Btu \cdot ft}{hr\ ft^2\ °F}$$ (average value for sand)

$$K_{water} = 0.35 \frac{Btu}{hr\ ft^2\ °F}$$

$$K_{water\ saturated\ soil} = y_{soil} K_{soil} + y_{water} K_{water} = 0.81\ (0.875) + 0.19\ (0.35)$$

$$= 0.78 \frac{Btu}{hr\ ft^2\ °F}$$

[Heat Loss = 0.78 $\frac{Btu}{hr\ ft^2\ °F}$ (10,947 ft) (80°F) = 683,000 Btu/hr]